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(71) Applicant (for all designated States except US): MINISTOR
PERIPHERAL INTERNATIONAL LIMITED [US/US];
2801 Orchard Parkway, San Jose, CA 95135 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): CHENG, Chunier, C.
[US/US]; 19433 DeHavilland Court, Saratoga, CA (US).
GOGUE, George, P. [US/US]; 9775 South West Rodeo
Place, Beaverton, OR 97005 (US). HAZEBROUCK, Henry,
B. [US/US]; 1145 W. McKinley Avenue, Sunnyvale, CA
94086 (US). MILLER, James, N. [US/US]; 950 University
Avenue, Palo Alto, CA 94301 (US). MURRAY, Reginald,
J. [US/US]; 3403 Wheeling Drive, Santa Clara, CA 95051
(US). RICHARDS, John, H. [US/US]; 3507 Nova Scotia
Avenue, San Jose, CA 95124 (US). SCHUH, Karl, D.
[US/US]; 5932 Indian Avenue, San Jose, CA 95123 (US).(74) Agents: RITCHIE, David, B. et al.; Suite 101, 2099 Lincoln
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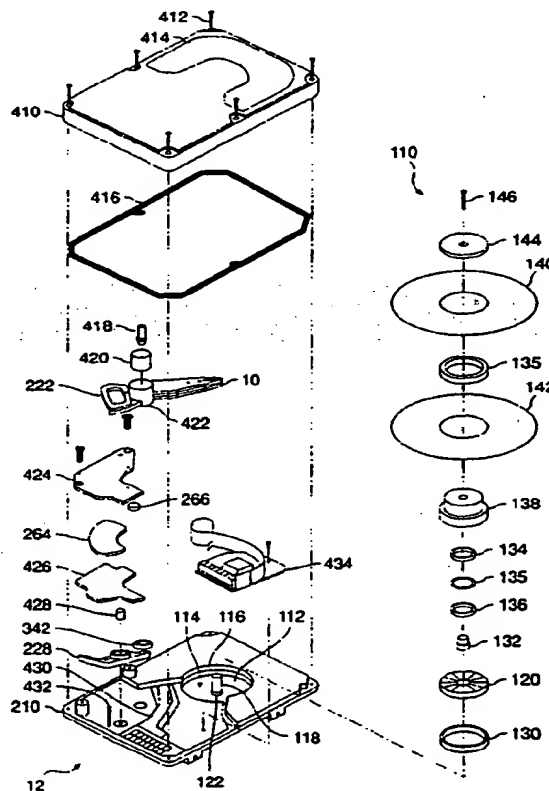
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(54) Title: ULTRA-SMALL FORM FACTOR DISK DRIVE APPARATUS

(57) Abstract

An ultra-small form factor disk drive system (12) of length about 86 mm, width about 54 mm and height about 13.5 mm or less is based on a 4.8 cm (1.89 in) diameter disk (20). The disk drive system is adapted to fit in an enclosure which is adapted to mate with and fit into a double high PCMCIA connector/slot and/or a triple high PCMCIA connector/slot. For the double high PCMCIA connector/slot, the height of the disk drive enclosure does not exceed 10.5 mm. The system may include a flying head and flexure assembly (34) incorporating a high offset and high preload head for improved head height control and increased recording density across the surface of the disk, a spindle motor (110) integral with the base plate (112) of the drive, a mechanical latch (230) for positive head actuator parking, and mechanical shock detection means (310) to prevent data corruption. The disk drive system can withstand 200 g shocks while operating.



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ULTRA-SMALL FORM FACTOR DISK DRIVE APPARATUS

TECHNICAL FIELD

The present invention relates to the field of data processing devices generally, and to peripheral devices for use with data processing devices, particularly to storage devices for use with small data processing devices such as lap-top and palm-top computers. More particularly, the present invention relates to such a storage device having an ultra-small form factor and which is adapted to fit into and mate to a double high or triple high PCMCIA connector/slot. In the case of a double high PCMCIA connector/slot, the width of the "PCMCIA drive" must be no more than about 5.4 cm (54 mm) and the height must be no more than about 1.05 cm (10.5 mm). In the case of the triple high PCMCIA connector/slot, the same width constraint applies but the height may be 1.35 cm (13.5 mm) or less.

BACKGROUND ART

There are numerous storage devices available for use with small computers, such as notebook, lap-top and even smaller palm-top computers. In currently available PC/AT based lap-top, notebook, and palm-top computers, the main mass storage device used is an IDE/AT rotating magnetic disk memory device. This IDE disk drive has the same task file register set defined by Western Digital and IBM about ten years ago with few intervening architectural modifications. The hardware interface is driven by a standard system BIOS software routine in the main CPU of the computing device. The hard disk BIOS is a well-defined system call, known as INT13, that allows a hook from the DOS operating system to access data on the disk. The DOS system driver calls INT13 with a set of given information on the type of disk operation to be performed, and the INT13 function performs all hardware interface operations with the disk drive. The disk drive responds to the INT13 operation by performing the given command, returns data via a CPU input/output move instruction, sets interrupts as each block of data is passed, and reports any errors.

Some of these small computer devices, especially palm-top computers, have been equipped with an interface for small credit-card like solid-state random access memory (RAM) memory devices. Such devices are manufactured to the Personal Computer Memory Card International Association (PCMCIA) interface standard and interface to the computer device through a standard 68 pin connector such as those available from Foxconn International of Sunnyvale, California. Due to customer memory requirements, computing devices which accept PCMCIA cards are often provided with the capability to simultaneously connect two of such PCMCIA cards to the computing device. Hardware for making such simultaneous connections is currently available from vendors, such as Foxconn International, which provides a dual deck 68 position PC card connector as part No. WFE 6857.

Providing a small computer, such as a lap-top or a palm-top computer, with a disk drive has proved to be a challenge for disk drive manufacturers. An ideal ultra-small form factor disk drive would ideally interface to such a small computing device through a double high PCMCIA slot and would also ideally fit within the volume of the card slot which two PCMCIA cards would occupy in the small computing device. Such a disk drive apparatus would be readily removable from the small computing device either for replacement by another ultra-small form factor disk drive or to transfer the information stored thereon to a larger desktop computer.

Due to the extremely restricted volume constraint imposed by the application environment, the design of an ultra-small form factor disk drive which can occupy the recessed volume provided in a small computing device for insertion of PCMCIA cards and can interface to the computing device through the PCMCIA interface connector has proved to be a difficult task. Design techniques which have been successfully employed in the design of larger disk drives, i.e., 13.335 cm (5.25 in), 8.89 cm (3.5 in), and 6.35 cm (2.5 in) form factor disk drives, cannot simply be incorporated into the design of such an ultra-small form factor disk drive apparatus.

It is therefore an object of the present invention to provide an ultra-small form factor disk drive apparatus having a disk diameter size of 4.8 cm (1.89 in)

or less, which can be physically interfaced to a small computing device such as a palm-top computer by inserting it into the recessed volume normally occupied by two PCMCIA cards (about 1.05 cm (10.5 mm) high) or three PCMCIA cards (about 1.35 cm (13.5 mm) high), and which can be electrically interfaced to the small computing device through the PCMCIA interface of the small computing device.

DISCLOSURE OF THE INVENTION

According to a first aspect of the present invention, an ultra-small form factor disk drive employing one or more storage disks, each having a diameter of 4.8 cm (1.89 in) or less, occupies a volume having a width of about 5.4 cm (54 mm) or less, a height of about 1.05 cm (10.5 mm) or less, and a length of about 8.6 cm (86 mm) or less. A PCMCIA connector is disposed at one end of the housing and positioned so as to mate with a mating PCMCIA connector in a double-high PCMCIA slot in a small computing device.

According to a second aspect of the present invention, an integral spindle-motor and base-plate assembly for the ultra-small form factor disk drive of the present invention includes a base plate comprising a frame for the entire disk drive assembly. The base plate has a width of about 5.4 cm (54 mm) or less and a length of about 8.6 cm (86 mm) or less, and includes a first generally cylindrical recessed portion into which an integral rotor/spindle assembly may be rotatably mounted onto a shaft or tower centrally located therein. A stator is mounted on a lower portion of the shaft or tower and an integral rotor/spindle assembly upon which one or more disks may be fixed is rotatably mounted on an upper portion of the base plate shaft by upper and lower bearings. Magnets are mounted on an annular portion of the integral rotor/spindle assembly which extends downward into the space between the outer edge of the stator and the wall defining the base plate recess. An HDA assembly, including control electronics, is mounted on the base plate with one or more stacked head actuators pivotally mounted and positioned such that a head mounted at a distal end of each one may be positioned to read from and write to one of the disks. The Z-height of the head actuator stacks is less than 0.0635 cm (0.025 in) and the HDA assembly is

mounted such that a second recess in the base plate provides clearance for the motion of the lower actuator arm. An actuator cover plate fits over the face of the base plate containing the HDA assembly.

5 A printed circuit board containing the control electronics for the disk drive has a width of no more than about 5.08 cm (50.8 mm), a length of no more than about 7.85 cm (3.09 in) without PCMCIA connector and no more than about 8.46 cm (3.33 in) with PCMCIA connector projecting horizontally therefrom, a thickness (of the circuit board) of no more than about 0.08 cm (0.8 mm), and is sandwiched between the base plate and a bracket/cover plate. A thin sheet of
10 insulating material is disposed between the printed circuit board and the base plate. The printed circuit board is provided with a circular aperture positioned so as to receive the recessed portion of the base plate when mounted thereon. Components are mounted on a first face of the printed circuit board facing away from the base plate to a height profile of about 0.17 cm (1.7 mm) and compo-
15 nents are mounted on a portion of the second side of the printed circuit board facing the base plate to a height profile of about 0.13 cm (1.3 mm) except in the area surrounding the recess in the base plate. No components are placed in the non-recessed area of the base plate. A PCMCIA connector is mounted on one edge of the printed circuit board along its width and protrudes horizontally
20 therefrom, between the base plate and the bracket/cover plate. The bracket/cover plate is provided with outwardly extending flanges along both of its length dimension edges, the flanges positioned to mate with guide slots on the host computing device which usually receive a PCMCIA card.

According to a third aspect of the present invention, the disk drive
25 apparatus of the present invention is provided with an arm-latching means, such as a static bistable mechanical actuator arm latch which, according to a presently preferred embodiment of the invention, comprises a latch member pivotally mounted to a frame. The latch member includes a first arm and a second arm radially extending from its pivot point. As will be more fully described later
30 herein, rotation of the latch member about the pivot point is mechanically confined between two fixed positions, an open position and a closed position.

The first arm includes a hooked end oriented with the open hook facing

the actuator and a magnetic material, such as an iron mass in the form of a small steel ball. The second arm includes an electromagnetic latch member coil or magnet mounted thereon, and/or an iron mass such as a small steel ball.

5 The second arm of the latch member is also provided with a laterally-protruding tang or bump. The mass of the latch member is preferably distributed such that the center of mass is at its pivot point and the angular mass moments on each side of the pivot point are thus canceled.

10 The actuator arm is pivotally mounted at a position which allows the head to be positioned anywhere in either a data area or landing zone of a magnetic disk. An end of the actuator opposite to the head mounting end is provided with a tip which nests into the hooked end of the latch member when the actuator is positioned such that the head is over the landing zone of the disk. The actuator is also provided with an angular protuberance which is positioned to engage the tang or bump on the second arm of the latch member when the actuator arm is moving towards the landing zone and is in a position close to the landing zone. 15 The actuator includes a coil used by the servo system of the drive to position the actuator in any angular position commanded.

20 The actuator coil is also positioned with respect to the permanent magnet assembly so as to allow control of the actuator position by controlling electric current passing through the actuator coil. The magnet assembly is configured and positioned such that its magnetic field force attracts the iron mass on the first arm of the latch member, applying a clockwise rotational force to the latch member, and attracts the iron mass on the second arm of the latch member, applying a counter-clockwise rotational force to the latch member.

25 The latch is activated when the power is cut to the spindle motor. Switching circuitry in the disk drive is activated to apply the back EMF generated by the still-rotating spindle motor to the actuator coil. The magnetic field produced around the actuator coil from the coil current resulting from the back EMF applies a torque to the actuator which rotates it in a direction such that the head moves towards the landing zone and the tip moves towards the hooked end of the latching member. When the angular protuberance on the actuator contacts the tang or bump, the actuator takes the latch member along and rotates the 30

hooked end of the latch member towards the tip of the actuator, thus nesting the tip in the hook and locking the actuator in the parked position. The magnetic attraction between the magnetic mass and the magnet assembly keeps the latch member in the closed position. The combination of the bump and hook on the latch member and the protuberance on the actuator arm keeps the tip positively nested in the lock.

In order to release the latch when it is desired to activate the drive and un-park the actuator, a current is passed through the actuator coil to move the tip counter-clockwise away from the hook, then a momentary current is passed through the latch member coil. The magnetic field created by the latch member coil current creates a magnetic attractive force between the latch member coil and the permanent magnet assembly. This force applies a rotational force to the latch member which rotates its first arm away from the actuator to release the actuator tip from its hooked end. At this moment, the polarity of the current passed through the actuator coil is reversed to rotate the actuator arm into a position over the data zone of a data disk. As the latch member and actuator rotate, the iron mass on the second arm of the latch member moves towards the magnetic assembly and the magnetic attraction between the iron mass on the second arm and the magnet assembly keeps the latch member in the open position after the power applied to the latch member coil is turned off.

According to a fourth aspect of the present invention, because the disk drive apparatus of the present invention is small in size, it is preferably provided with means for preventing data corruption due to mechanical shock experienced by the disk drive during the write process. Mechanical shock sensing means are provided to sense mechanical shocks having a magnitude exceeding a predetermined threshold. Write disable means responsive to the mechanical shock sensing means is activated and interrupts the write current to the disk drive write head when a mechanical shock is sensed. Recovery means are provided to reposition the head to the original data track and rewrite the incompletely written data that was interrupted by the mechanical shock. Thus, the mechanical shock causes only a minor delay to the user, but prevents corruption of the data on adjacent tracks by write head misalignment caused by the mechanical shock.

According to a fifth aspect of the present invention, in a 4.8 cm (1.89 in) HDD employing a pivotable flexure assembly aligned so that the skew angle is relatively low at the inner diameter of the useable disk surface and on which is mounted a magnetic read/write head assembly, the centerline of the slider comprising the magnetic head assembly is mounted parallel to and at an offset in excess of 3.5 mils (0.0035", 0.00889 cm) inboard of the centerline of the flexure assembly. The increased offset further decreases the lift of the head at the outer diameter of the disk in the airstream created by the rotation of the disk surface without significantly increasing the aerodynamic instability of the head.

According to a sixth aspect of the present invention, a pre-load exceeding 3.5 grams is utilized to further control the flying height of the head across the surface of the disk so that it is relatively constant from the inner tracks through the middle tracks and out to the outer tracks.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a top view of a Hutchinson type T-16 suspension.

Fig. 1B is a side view of a Hutchinson type T-16 suspension in a loaded configuration.

Fig. 1C is a side view of a Hutchinson type T-16 suspension in an unloaded configuration.

Fig. 2 is a perspective view of a 50% "nano slider" twin taper flat slider comprising a thin film read/write transducer element.

Fig. 3A is a top view of a Hutchinson type T-16 suspension with slider attached.

Fig. 3B is a side view of an unloaded Hutchinson type T-16 suspension with slider attached.

Fig. 3C is a side view of a loaded Hutchinson type T-16 suspension with slider attached.

Fig. 3D is a view along section line 3D-3D of Fig. 3A.

Fig. 4A is a side view of the tip of a Hutchinson type T-16 suspension with slider attached.

Fig. 4B is a bottom view of the tip of a Hutchinson type T-16 suspension

with slider attached.

Figs. 5, 5A and 5B are a top view, sectional view along section line 5A-5A, and sectional view along section line 5B-5B, respectively, of a disk drive according to a preferred embodiment of the present invention.

5 Fig. 6 is a diagram showing a cross-sectional view of an integral spindle-motor base-plate assembly for a small form factor disk drive according to the present invention.

10 Fig. 7 is a top view of a disk drive mechanism including a bistable mechanical actuator latch according to a presently preferred embodiment of the invention.

Fig. 8A is a magnified portion of the disk drive mechanism of Fig. 7, showing the actuator arm in the free position and the latch member in the open position.

15 Fig. 8B is a magnified portion of the disk drive mechanism of Fig. 7, showing the actuator arm in the parked position and the latch member in the closed position.

Fig. 9A is a top view of a presently preferred pivoting latch arm for use in the bistable latch apparatus of Fig. 7.

20 Fig. 9B is a cross-sectional view of the pivoting latch arm of Fig. 9A, taken through section line 9B-9B.

Fig. 10A is a side view of a presently preferred cover plate and magnet assembly for use in the bistable latch apparatus of Fig. 7.

Fig. 10B is a top view of a presently preferred cover plate and magnet assembly for use in the bistable latch apparatus of Fig. 7.

25 Fig. 11 is a block diagram of an apparatus for preventing data corruption on a disk due to mechanical shock experienced by the disk drive during the writing of data to a selected data track on the disk according to a presently preferred embodiment of the invention.

30 Fig. 12A is a side view diagram of a single-beam cantilever beam rotational accelerometer for shock sensing in the apparatus of the present invention.

Fig. 12B is a top view diagram of the single-beam cantilever beam rotational accelerometer of Fig. 12A.

Fig. 12C is a side view diagram of a dual-beam cantilever beam rotational accelerometer, presently preferred for shock sensing in the apparatus of the present invention.

5 Fig. 12D is a top view diagram of the dual-beam cantilever beam rotational accelerometer of Fig. 12C.

Fig. 13 is a flow diagram illustrating the steps of a method for preventing data corruption in disk drives from mechanical shock during write operations according to a presently preferred embodiment of the invention.

10 Fig. 14 is an exploded perspective view of the hard disk drive assembly according to a preferred embodiment of the present invention.

Fig. 15 is an exploded perspective view of the ultra-small form factor disk drive assembly.

Figs. 16A and 16B are connector pad diagrams of the printed circuit board assembly for the drive electronics.

15 Figs. 17A, 17B and 17C are top, side and front views of the ultra-small form factor disk drive assembly.

BEST MODES FOR CARRYING OUT THE INVENTION

Those of ordinary skill in the art will realize that the following description of the present invention is illustrative only and not in any way limiting.
20 Other embodiments of the invention will readily suggest themselves to such skilled persons.

As the sizes of computing devices shrink, and portability becomes an important feature of these devices, the industry has responded by providing convenient memory in the form of credit-card like memory cards which may be
25 interchangeably inserted into slots in the computing devices. These cards, and the electrical interfaces for them in the computing devices are currently manufactured to the Personal Computer Memory Card International Association (PCMCIA) interface standards and interface to the computing devices through a 68 pin connector.

30 As will be appreciated by those of skill in the art, a 1.89" Hard Disk Drive ("HDD") which fits in and interfaces to a double high PCMCIA connector/slot

arrangement will provide several previously unavailable features and advantages such as, for example, easy transportability of large quantities (up to about 130 megabytes) of data in a compact device capable of being carried in a pocket.

Thus a user may without difficulty carry his or her disk drive containing data and software from machine to machine and plug it in anywhere an appropriate connector/slot is available. Similarly, large programs may be distributed ready to "plug and play" rather than on floppy disks which generally requires the user to transfer the contents of the floppy disks to a hard disk drive and then set the software up to operate properly on the particular computer.

There are presently two preferred embodiments of the ultra-small form factor disk drive capable of fitting into and mating to a double high PCMCIA connector/slot. The relevant specifications of each is set forth in Tables I and II below:

TABLE Ia**VERSION I (Adheres to PCMCIA Standard for Type III Cards)****Architecture and Performance**

5	Capacity:	42 Mbytes, formatted
	Sector size:	512-bytes
	Disks:	1
	Heads:	2
	Tracks/Cylinder:	2
	User cylinders:	1062
10	Seek times:	16ms average 30ms fullstroke 6ms single track
	Power on-Interface Ready:	100ms
	Exit Standby-Data Avail:	1.5 seconds
15	Standby to Spindle Stop:	1.0 seconds
	Power Off to Spindle Stop:	2.5 seconds
	Latency:	6.67 ms average
	Servo:	sectored
	Sealed H.D.A.	

Interface

20	PCMCIA/ATA Compatible
	32 Kbyte buffer
	11 byte Reed Solomon on-the-fly error correction
	Programmed I/O up to 5 Mbytes/second
25	Cache mode operation, read lookahead

Recording Parameters

	Track density:	1019 tracks per cm (2587 tpi)
	Recording density:	55.3 Kbp/41.5Kfci (variable)
	Recording code:	2/3 1,7 RLL
30	Recording format:	zone density, 8 zones
	Recording interface:	film heads and media
	Data transfer rates id/od:	11.86/21.52 Mbit/second

Acoustic Noise

35	Idle:	32 dBA max per ISO spec
	Seeking:	34 dBA max per ISO spec

TABLE Ib**Power Requirements**

+5 Volts, +/- 5%

5	Start up:	500 mA/3.0 w
	Idle:	120 mA/0.60 w
	Seek:	250 mA/1.25 w
	Read/Write:	300 mA/1.5 w
	Sleep:	20 mA/0.1 w
	Deep Sleep:	1 mA/0.005 w

10 **Reliability**

MTBF:	250,000 hours
Starts/Stops:	100,000
Unrecoverable errors	< 1 in 10E14 bits with ECC

Environmental

15	Operating temperature:	+5 to +55 degrees C.
	Non-operating temp.:	-40 to +70 degrees C.
	Operating shock:	200 G
20	Non-operating shock:	200 G
	Rotational Acceleration:	1500 radian/sec ²
	Humidity: Operating:	5% to 95% non-condensing
	Non-Operating:	5% to 95% non-condensing
	Altitude: Operating:	12.192 km (40,000 ft)
	Non-Operating:	12.192 km (40,000 ft)

Physical Dimensions

25	Length:	8.56 cm (85.6 mm)
	Width:	5.40 cm (54.0 mm)
	Height:	1.03 cm (10.3 mm)
	Weight:	68.3 grams (nominal)

Magnetic Field

30	External:	5 Gauss max at disk surface
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TABLE IIa**VERSION II (Compatible with PCMCIA Standard for Type III Cards)****Architecture and Performance**

	Capacity:	130 Mbytes, formatted
5	Sector size:	512-bytes
	Disks:	2
	Heads:	4
	Tracks/Cylinder:	4
	User cylinders:	1218
10	Seek times:	16ms average; 30ms fullstroke; 6ms single track
	Power on-Interface Ready:	100ms
	Exit Standby-Data Avail:	1.5 seconds
	Standby to Spindle Stop:	1.0 seconds
	Power Off to Spindle Stop:	2.5 seconds
15	Latency:	6.72 ms average
	Servo:	sectored
	Sealed H.D.A.	

Interface

	PCMCIA/ATA Compatible
20	32 Kbyte buffer
	11 byte Reed Solomon on-the-fly error correction
	Programmed I/O up to 5 Mbytes/second
	Cache mode operation, read lookahead

Recording Parameters

25	Track density:	3100 tpi
	Recording density:	73.0 Kbp/54.8Kfci (variable)
	Recording code:	2/3 1,7 RLL
	Recording format:	zone density, 8 zones
	Recording interface:	film heads and media
30	Data transfer rates id/od:	14.5/28.0 Mbit/second

Acoustic Noise

	Idle:	32 dBA max per ISO spec
	Seeking:	34 dBA max per ISO spec

Power Requirements

35	+5 Volts, +/- 5%	
	Start up:	600 mA/3.0 w
	Idle:	145 mA/0.73 w
	Seek:	300 mA/1.5 w
	Read/Write:	350 mA/1.75 w
40	Sleep:	20 mA/0.1 w
	Deep Sleep:	1 mA/0.005 w

TABLE IIb**Reliability**

	MTBF:	250,000 hours
	Starts/Stops:	100,000
5	Unrecoverable errors:	< 1 in 10E14 bits with ECC

Environmental

	Operating temperature:	+5 to +55 degrees C.
	Non-operating temp.:	-40 to +70 degrees C.
	Operating shock:	200 G
10	Non-operating shock:	200 G
	Rotational Acceleration:	1500 radian/sec ²
	Humidity: Operating:	5% to 95% non-condensing
	Non-Operating:	5% to 95% non-condensing
	Altitude: Operating:	40,000 ft.
15	Non-Operating:	40,000 ft.

Physical Dimensions

	Length:	85.6 mm
	Width:	54.0 mm
	Height:	10.5 mm
20	Weight:	80.0 grams (nominal)

Magnetic Field

	External:	5 Gauss max at disk surface
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Several novel features have been developed in order to realize the "PCMCIA drive." These will now be discussed.

Flying Head and Flexure Assembly

HDDs make use of magnetic read/write head assemblies which comprise magnetic pick-ups or "heads" mounted on sliders which are, in turn, mounted on flexure assemblies. The flexure assembly is radially positioned so that the heads are positioned over a particular circular track a predetermined radius from the center of rotation of the disk. Pivoting the flexure assembly causes the heads to be positioned over another track.

4.8 cm (1.89 in) HDDs may have their innermost track located about 1.194 cm (0.47 in) from the center of the disk and their outermost track located about 2.291 cm (0.902 in) from the center of the disk. At a rotational speed of about 4500 RPM the linear velocity of the tracks speeding beneath the head ranges from about 561.34 cm per second (221 inches per second) at the innermost track to about 1079.5 cm per second (425 inches per second) at the outermost track. As a result of well-known aerodynamic effects, the slider "flies" over the surface of the rigid disk. The fact that the relative linear speed of the slider and disk is different between the innermost track and the outermost track poses problems in control of the head height over the disk surface just as an airplane tends to fly higher if it goes faster.

An artifact of using a pivotable flexure assembly which pivots about a fixed point is that while the slider may be positioned perfectly tangentially with respect to one track of the disk, it will form an angle with respect to the tangent of the disk in all other tracks. This angle is known as the skew angle. Generally the skew angle is set so that it is relatively low at the innermost track (head centerline nearly parallel to track tangent at the head) and increases toward the outermost track. The advantage of this configuration is that the aerodynamics of the slider cause it to have the most lift at low skew angles and less lift at high skew angles, thus the slider tends to gain less altitude over the disk surface at the outermost track despite the increase in relative linear speed.

The recording density that can be achieved in an HDD depends, in part,

upon the distance between the recording head and the recording medium. The highest recording densities are achieved with the head as close to the surface of the disk as possible without running a risk of a head crash. In order to maximize the amount of data which can be stored upon an HDD, it is desirable that the head be at approximately the same minimum height above the disk surface at all tracks. Prior art techniques for head control do not permit such fine control of the head height in 4.8 cm (1.89 in) drives and have resulted in the head flying higher at the outermost tracks than it does in the tracks inboard (closer to the center of the disk) of the outermost tracks. Accordingly, the highest possible data densities are not achieved in those outer tracks. As the outer tracks contain proportionately more of the surface area of the HDD available for recording data than do the more inward tracks, the potential storage capabilities of such disk drives are not realized and the loss is significant.

For some time, it has been known that if the head is mounted slightly inboard of the centerline of the flexure arm of the flexure assembly, that additional control over head height may be obtained. However, all known implementations of offset heads for 4.8 cm (1.89 in) drives have been within the specifications of the flexure manufacturer for offset which are that the offset should not exceed 3.5 mils (0.0035", 0.00889 cm) of outward offset so as not to interfere with the operation of the gimbal assembly or cause flight instabilities for the slider.

Another technique used to keep the head close to the disk surface is called "gram loading" or "pre-load". Pre-load is the nominal downward force applied by the flexure to the head which forces it against the disk surface. Common prior art pre-loads for 4.8 cm (1.89 in) disk drives do not exceed 3.5 grams so as to avoid the risk of stiction and head crashes.

According to the present invention as described below, significantly improved head height control across the entire surface of a 4.8 cm (1.89 in) HDD is achieved by use of an inboard head offset exceeding 3.5 mils (0.0035", 0.00889 cm) and by use of a pre-load exceeding 3.5 grams.

In a 4.8 cm (1.89 in) diameter hard disk drive according to a presently preferred embodiment of the present invention, a pivotable head

actuator assembly 10 is provided. Head actuator assembly 10 (also known as a "head/gimbal assembly" or "HGA") shown in Fig. 3A is as seen from the top looking down toward the surface of a magnetic disk. Shown is a "down configuration" version of head actuator assembly 10.

Turning now to Figs. 5, 5A and 5B, a top view of disk drive 12 is shown in Fig. 5. Head actuator assembly 10 pivots about pivot point 14. Tip 16A of head actuator assembly 10 is shown positioned over innermost track 18 of disk 20. Tip 16B of head actuator assembly 10 is shown positioned over outermost track 22 of disk 20. Disk 20 rotates counterclockwise about center 24 of disk 20.

Innermost track 18 is preferably located about 1.194 cm (0.47 in) from center 24 of disk 20 and outermost track 22 is located a maximum of about 2.291 cm (0.902 in) from center 24 of disk 20. Disk 20 preferably rotates in operation at a speed of about 4500 RPM. The linear velocity of disk 20 speeding beneath head actuator assembly 10 ranges from about 561.34 cm per second (221 inches per second) while head actuator assembly 10 is positioned over innermost track 18 (16A) to about 1079.5 cm per second (425 inches per second) while head actuator assembly 10 is positioned over outermost track 22 (16B).

Head actuator assembly 10 preferably comprises a thin film read/write transducer element 26 comprising magnetic pick-ups 28, 30 attached to slider body 32 that is in turn adhesively bonded to suspension (or "flexure") 34. A bi-filar lead wire 36 has a first end 38 ultrasonically bonded to slider body 32 and a second end soldered to two lead paddle board 42. Tubing 44 through which lead wire 36 is routed is provided for protection of lead wire 36.

According to a presently preferred embodiment of the present invention, the skew angle is set to 1.43° at innermost track 18 and increases to over 16.37° at outermost track 22. The recording density (BPC = bits per linear cm; BPI = bits per linear inch) at innermost track 18 is about 18373 BPC (46667 BPI) and ranges to about 19396 BPC (49267 BPI) at outermost track 22. Over this range the head height in operation ranges from a minimum of about 0.00000584 cm (2.3 microinches) to about 0.00001143 cm (4.5 microinches) above the surface of disk 20.

As can be seen in Figs. 1B, 1C, 3B, and 3C, flexure 34 is designed

to exert a downward force or "preload" on slider body 32. In the unloaded position shown in Figs. 3B and 1C flexure 34 is shown bent. In the loaded position shown in Figs. 3C and 1B, flexure 34 is shown straight but is exerting a downward directed force upon slider body 32. Preferably the "preload" (or "gram load" as it is sometimes called) is set to be at least 3.5 grams and preferably about 4.5 grams.

Turning to Figs. 1A-1C flexure 34 is shown without any additional components. Flexure 34 is preferably a Hutchinson Technology type T-16 or T-1650 suspension available from Hutchinson Technology of Hutchinson, Minnesota. A type T-1650 suspension known as the "1650 Interlock" suspension is currently preferred for the 1.05 cm (10.5 mm) thick version of the PCMCIA drive having two disks. The 1650 Interlock Suspension permits the suspensions to share the same boss. Type T-16 and both T-1650 suspensions are identical for the purposes herein described. Accordingly, "T-16" will refer to both T-16 and T-1650 flexures herein. Flexure 34 includes a gimbal assembly 48 to which slider body 32 is bonded. Gimbal assembly 48 provides a gimbaled attachment of slider body 32 to flexure 34.

Turning now to Fig. 2, a slider body 32 is shown in perspective view. Side 46 of slider 32 is designed to be nearly in contact with the surface of disk 20 during operation. Slider body 32 acts like a miniature airplane wing under the aerodynamic conditions present in disk drive 12. Slider body 32 is preferably a 50% ("nano slider") twin taper slider available, for example, from Dastek of San Jose, California or Read-Rite Corporation of Milpitas, California. Slider body 32 includes ramps 50 and 52 at its leading edge, air bearing surfaces 54, 56 and thin film read/write transducer element 26 which comprises magnetic pick ups 28, 30. Preferably slider body 32 is bonded to gimbal assembly 48 so that the centerline 58 of slider body 32 is oriented parallel to and at least 3.5 mils (0.0035", 0.00889 cm) (and preferably about 4.5 mils (0.0045", 0.01143 cm)) inboard of the centerline 60 of flexure 34. Inboard means closer to center 24 of disk 20. In this manner, improved head height stability and control is obtained across the surface of disk 20 leading to increased realized recording density at the extremities of disk 20.

Spindle Motor Assembly

5 Disk drive data storage mechanisms include a spindle motor to provide the driving torque for rotation of the disks. The spindle motor assembly, along with the actuator arm assembly, servo electronics, and other electronic circuitry, are usually mounted together on a base plate, which is then placed in a suitable mechanical enclosure. As computer systems shrink in physical size, the disk drive mechanisms which are incorporated into them must also become smaller in size. This presents a challenge to the disk drive designer, who must incorporate the full functionality of the drive into a greatly-reduced volume.

10 There have been several prior art approaches to providing the spindle-motor mounting in a disk drive mechanism. A first approach employs a spindle shaft plate, including a spindle shaft, which mounts on a base plate. A stator is mounted on the spindle shaft between a set of upper and a set of lower bearings, upon which the rotor is mounted and rotates.

15 In a second approach, the spindle shaft is fixed to the rotor. The spindle shaft passes through the center of the stator attached to a mounting assembly and is mounted on one or more sets of bearings attached to the mounting assembly.

20 Examples of prior art disk drive spindle motor assemblies include those disclosed in United States Patents Nos. 4,943,748 to Shiozawa; 4,965,476 to Lin; 5,013,947 to Ide; 5,015,893 to Shiozawa; and 5,040,085 to Elsässer et al.

25 United States Patent Nos. 4,943,748 and 5,015,893 to Shiozawa disclose a motor assembly useful in disk drive apparatus. The motor is fabricated on a frame which may be placed in a disk drive. A stator is coaxially mounted over a set of bearings on a spindle shaft. The bearings fit within the inner diameter of the stator. A disk hub is mounted on the shaft in a position above the bearings. A magnet assembly is circumferentially mounted to the disk hub and extends downward and lies outside of the stator.

30 United States Patent No. 4,965,476 to Lin discloses a motor assembly useful in disk drive apparatus. The motor is fabricated on a frame which may be mounted in a disk drive. In two disclosed embodiments (i.e., Figs. 1 and 5), a stator is mounted co-axially with a set of bearings on a spindle shaft. The inner diameter of the stator lies outside the outer diameter of the bearing assembly.

In another embodiment (i.e., Fig. 3), a stator is mounted below a set of bearings on a spindle shaft hub. The inner diameter of the stator in this embodiment also lies outside the outer diameter of the bearing assembly.

United States Patent No. 5,013,947 to Ide discloses a motor assembly useful in disk drive apparatus employing a gas-lubricated spindle shaft in a motor otherwise employing conventional electromagnetic motor components.

United States Patent No. 5,040,085 to Elsässer et al discloses a motor assembly useful in disk drive apparatus. The disk mount portion of the hub is coincident with the stator windings and rotor magnet. The stator lies outside of the bearing assembly, its inner diameter lying outside of the outer diameter of the bearing assembly. The stator is positioned between the two sets of bearings.

While the disk drive spindle motors described in the prior art have proved to be useful, there remains room for improvement, especially for motor assemblies which may be employed in small form factor disk drives, where the prior art spindle configurations can no longer be optimally employed. This is true for two reasons.

First, the ball bearings in small drives can undergo severe shock load during handling and must thus be proportionally larger compared to the overall spindle size. This would necessarily make the inside diameter of the stator larger, thus reducing the available volume for the stator windings and limiting the torque which can be produced by the motor.

The second problem is that, as the disk hub diameters get smaller, stators such as those employed in United States Patents 4,965,476 to Lin; 5,013,947 to Ide; and 5,040,085 to Elsässer et al., have much smaller diameters, thus reducing to unacceptably low levels the torque which the motor is capable of producing.

Referring now to Figs. 6 and 14, Fig. 6 is a diagram which illustrates a cross-sectional view of an integral spindle-motor base plate assembly for a small form factor disk drive according to a presently preferred embodiment of the invention. Fig. 14 is, in part, an exploded view thereof. The motor assembly 110 of the present invention is integrated into a base plate 112 upon which the other components of the drive may be mounted. Base plate 112 may comprise a sheet metal stamping or a die casting and includes a generally circular-shaped recessed

portion 114 defined by an inner wall 116 into which a rotor assembly may be received. A spindle shaft 118, either integrally formed with or affixed to base plate 112, is provided at the center of recessed portion 114. A stator 120 is mounted around and affixed to the lower portion of spindle shaft or tower 118. Fig. 6 illustrates stator 120 resting on top of a shoulder 122 provided on spindle shaft 118. The outer diameter of stator 120 is selected so as to leave an annular cavity 124 between its outer diameter and the inner wall 116 which defines recessed portion 114 of base plate 112.

Annular cavity 124 has a width large enough to allow for clearance of the thickness of rotor 128 and its annular magnet 130. Rotor 128 is mounted on a bearing shaft 132 by means of upper and lower bearings 134 and 136 disposed on bearing shaft 132 and separated by bearing spacer 135. Bearing shaft 132 is then mounted on the spindle shaft 118.

The upper portion of rotor 128 comprises a cylindrical disk hub 138 upon which a plurality of disks, shown in cut away cross-section illustratively as two disks 140 and 142, may be mounted by means of a disk clamp 144 held down by a single disk clamp screw 146 held in an axial threaded hole 148 in hub 138. Disk spacer 150 is used to separate disks 140 and 142. Annular magnet 130 is affixed to the lower portion 152 of rotor 128, which may be in the form of a cylindrical band. When rotor 128 is in its assembled position on upper and lower bearings 134 and 136, its lower portion 152 and annular magnet occupy the annular cavity 124 with operative clearance between the outer diameter of stator 120 and inner wall 116 denning recessed portion 114 of base plate 112.

Those of ordinary skill in the art will appreciate that the integral spindle-motor base plate assembly of the present invention facilitates the fabrication of small form factor disk drives. A disk drive having a height profile of about 13.5 mm or less (about 10.5 mm or less according to a preferred embodiment hereof) and disk inner diameters of about 12 mm or less can be realized by employing the integral spindle-motor base plate assembly of the present invention. In an illustrative embodiment of the present invention comprising a 4.8 cm (1.89 in) form factor disk drive, a 4,500 RPM spindle motor made in accordance with the teachings of the present invention may employ an eight pole annular magnet 130

having an outside diameter of about 1.676 cm (0.66 in), an inside diameter of about 1.473 cm (0.58 in), a height of about 0.33 cm (0.13 in), formed from a radial anisotropic magnetic material, a nine winding stator having about 83 turns of 37 AWG copper wire. The motor may be disposed in a plate recess having a diameter of about 1.88 cm (0.74 in).

By configuring the motor assembly according to the present invention, with the bearings positioned above the stator and no mutual constraint between the outside diameter of the bearings and the inside diameter of the stator, sufficiently large bearings can be used to withstand expected shock loads without affecting the inner diameter of the stator.

In addition, because the stator and rotor magnet are placed below the level of the lowest disk mounted on the hub 138, the diameters of the rotor and stator magnets are not constrained to be within the inner diameter of the disks. This allows the motor to be designed to produce sufficient torque to meet startup requirements.

Two additional benefits are derived from the motor of the present invention. First, the design of the base shaft 118 and hub 138 allow a single disk clamp screw 146 to be used at the center of the hub 138. Use of a single screw is the best way to assure a uniform clamping pressure around the circumference of the disk, an important requirement in high performance disk drives. Prior art designs have not provided the advantage of the combination of a stationary shaft and a single disk clamp screw in the center of the hub which is provided by the present invention.

Second, by building the motor directly on the drive baseplate, the space which would otherwise be required for mounting the spindle flange to the baseplate is eliminated, permitting a smaller footprint design.

Head Actuator Parking Mechanism

Most disk drives are equipped with some type of arrangement which provides for securing or "parking" the head actuators so that the heads may be held immobilized over a landing zone on a disk at times when the drive is not in use, such as during transportation of the disk drive or the computer in which it

is installed. These mechanical latching devices typically comprise either magnetic or mechanical, or a combination of magnetic and mechanical latching means.

Historically, disk drives started as very large immovable devices, weighing over 2000 pounds, and having disk diameters ranging from 2 to 4 feet. Disk sizes have quickly evolved to 35.56 cm (14 in), 13.335 cm (5.25 in), 8.89 cm (3.5 in), 6.35 cm (2.5 in) and smaller. As development continues, disk drives are continually shrinking in size to accommodate new applications.

As disk diameters, and hence the drives which contain them become smaller, different issues arise in the design of actuator "parking" mechanisms. As continuing evolution shrinks disk diameters below 5.08 cm (2 in), mechanical shock becomes an increasingly larger concern in the design of head parking mechanisms. Larger disk drives (i.e., 13.335 cm (5.25 in) and 8.89 cm (3.5 in)) are generally mounted into computer systems housed in larger cases, usually residing on desk tops, or in even larger "tower" cases which are placed on the floor. In these environments, design of actuator latches for larger disk drives, even the 13.335 cm (5.25 in) and 8.89 cm (3.5 in) drives, are relatively free from constraints relating to mechanical shocks because the likely-to-be-encountered mechanical shock forces are small compared to the force with which a latch can hold the actuator arm. In addition, because such devices are powered from power supplies connected to electrical utility distribution systems, power consumption is not an issue and can be continuously supplied to a disk drive latching mechanism when desired. The absence of power and space constraints gives the mechanical designer a wide range of options when designing a latching mechanism.

The present concern over mechanical shock as an issue in the design of latching mechanisms results from the development of the small disk drives which are designed to reside in small lap-top and notebook computers and the problems which are presented to designers because of size and other requirements. Such applications present an environment in which bumping and jostling is much more likely. A lap-top computer system weighs from about 5 to 15 pounds. This lower weight increases the likely-to-be-encountered mechanical shock forces which have to be taken into consideration. Such forces are significantly larger than those likely to be encountered in larger disk drives in comparison to the force that an

actuator is capable of generating. This means that the ideal latching mechanism has to provide enough latching force to keep the actuator in the desired landing zone position during parking. However, due to the smaller size of the drives, this requirement competes with the requirement that the force necessary to free the actuator from its parked position be reasonably available in the small disk drive.

In addition, the applications for which the smaller disk drive units are being considered are largely notebook, lap-top, and palm-top computer applications. Since these smaller computers are designed to be portable and are thus powered for the most part by batteries, power-management considerations require that the disk drives be operable with a minimum amount of power. Furthermore, most such applications require extremely low standby-power requirements for the disk drives when they are not being written to or read from. This power-management requirement restricts latching designs to static embodiments which do not continuously consume power.

Finally, as disk drive sizes continue to shrink, the amount of data area available on the disk decreases. It is thus desirable to maximize the free movement of the actuator to maximize the data area without having to sacrifice movement, and hence useable disk data area, to accommodate the latching mechanism.

These considerations present a significant challenge to the disk drive designer. There is a need for providing a reliable actuator latching mechanism which is adaptable to the several design requirements of small disk drives.

According to a presently preferred embodiment of the invention, a static bistable mechanical latch for a disk drive actuator arm comprises a latch member pivotally mounted to a frame. The latch member includes a first arm and a second arm radially extending from its pivot point. As will be more fully described later herein, rotation of the latch member about the pivot point is mechanically confined between two fixed positions, an open position and a closed position.

The first arm includes a hooked end oriented with the open hook facing the actuator and a magnetic material, such as an iron mass in the form of a small steel ball. The second arm includes an electromagnetic latch member coil or

magnet mounted thereon, and/or an iron mass such as a small steel ball.

The second arm of the latch member is also provided with a laterally-protruding tang or bump. The mass of the latch member is preferably distributed such that the center of mass is at its pivot point and the angular mass moments on each side of the pivot point are thus canceled.

An actuator to be parked using the apparatus of the present invention comprises an arm with a read/write head affixed to a first end thereof. The actuator arm is pivotally mounted at a position which allows the head to be positioned anywhere in either a data area or landing zone of a magnetic disk. A second end of the actuator is provided with a tip which nests into the hooked end of the latch member when the actuator is positioned such that the head is over the landing zone of the disk. The actuator is also provided with an angular protuberance which is positioned to engage the tang or bump on the second arm of the latch member when the actuator arm is moving towards the landing zone and is in a position close to the landing zone. The actuator includes a coil used by the servo system of the drive to position the actuator in any angular position commanded.

The actuator coil is also positioned with respect to the permanent magnet assembly so as to allow control of the actuator position by controlling electric current passing through the actuator coil. The magnet assembly is configured and positioned such that its magnetic field force attracts the iron mass on the first arm of the latch member, applying a clockwise rotational force to the latch member, and attracts the iron mass on the second arm of the latch member, applying a counter-clockwise rotational force to the latch member.

The latch is activated when the power is cut to the spindle motor. Switching circuitry in the disk drive is activated to apply the back EMF generated by the still-rotating spindle motor to the actuator coil. The magnetic field produced around the actuator coil from the coil current resulting from the back EMF applies a torque to the actuator which rotates it in a direction such that the head moves towards the landing zone and the tip moves towards the hooked end of the latching member. When the angular protuberance on the actuator contacts the tang or bump, the actuator takes the latch member along and rotates the

hooked end of the latch member towards the tip of the actuator, thus nesting the tip in the hook and locking the actuator in the parked position. The magnetic attraction between the magnetic mass and the magnet assembly keeps the latch member in the closed position. The combination of the bump and hook on the latch member and the protuberance on the actuator arm keeps the tip positively nested in the lock.

In order to release the latch when it is desired to activate the drive and un-park the actuator, a current is passed through the actuator coil to move the tip counter-clockwise away from the hook, then a momentary current is passed through the latch member coil. The magnetic field created by the latch member coil current creates a magnetic attractive force between the latch member coil and the permanent magnet assembly. This force applies a rotational force to the latch member which rotates its first arm away from the actuator to release the actuator tip from its hooked end. At this moment, the polarity of the current passed through the actuator coil is reversed to rotate the actuator arm into a position over the data zone of a data disk. As the latch member and actuator rotate, the iron mass on the second arm of the latch member moves towards the magnetic assembly and the magnetic attraction between the iron mass on the second arm and the magnet assembly keeps the latch member in the open position after the power applied to the latch member coil is turned off.

Referring first to Figs. 7, 8A and 8B, a top view of a disk drive including the apparatus of the present invention is shown (Fig. 7) and magnified top views of the portion of the disk drive of Fig. 7 (Figs. 8A and 8B) are shown. The disk drive is disposed upon a disk drive frame 210, on which is mounted spindle motor 212 carrying disk 214, and actuator 216 with arms 218 and 220 positioning coil 222 and head 224. Actuator 216 is pivotally mounted to frame 210 at actuator pivot point 226.

As shown in Figs. 7, 8A, 8B, 9A and 9B, according to a presently preferred embodiment of the invention, a static bistable mechanical latch 228 for disk drive actuator 216 comprises a latch member 230 pivotally mounted to frame 210 at latch member pivot point 232. As may be easily seen from Figs. 8A, 8B, 9A, and 9b, latch member 230 includes a first arm 234 and second arm 236 radially

extending from its pivot point 232. First arm 234 is equipped with a hook 238 oriented such that the open hook faces the end of the actuator arm opposite the head-carrying end. First arm 234 also includes an iron mass 240, preferably in the form of a steel ball.

5 Second arm 236 includes an electromagnetic latch member coil 242 mounted thereon, preferably at or near the end furthest from the pivot point. A pair of electrical leads 244 are used to provide current to latch member coil 242. Second arm 234 also includes an iron mass 246, preferably in the form of a steel ball. Second arm 236 is also provided with a tang or bump 248 extending laterally
10 in a direction towards actuator arm 220. An open-position stop 250 and a closed-position stop 252 are mounted on frame 210 at selected positions in the path of first arm 234. The positions of open-position stop 250 and closed-position stop 252 are chosen to restrict the rotational motion of latch member 230 as will be more fully explained herein.

15 The mass of latch member 230 is preferably distributed equally over first arm 234 and second arm 236 such that the center of mass is at its pivot point to cancel the angular moments on each side of the pivot point. The only force which thus appreciably affects latch member 230 is the rotational force applied by the co-operating elements of the present invention, or unintended external
20 shock, vibration, or rotational shock load.

 Actuator 216 for use with the apparatus of the present invention comprises a pivotally mounted arm 218 with a read/write head 224 affixed to one end thereof. Actuator pivot point 226 allows head 224 to be positioned anywhere in either the data area 254 or the landing zone 256 of disk 214 (Fig. 7). Actuator
25 216 is provided with a tip 258, preferably located at the end thereof opposite to the end upon which head 224 is mounted. Tip 258 is shaped to nest into the hooked end 238 of latch member 230 when actuator 216 is positioned such that head 224 is located over landing zone 256 of disk 214. Fig. 8A shows actuator 216 in the free position and Fig. 8B shows actuator 216 in the latched position
30 with its tip 258 nested into hooked end 238 of latch member 230.

 Actuator coil 222 is mounted at the end opposite to head 224. Actuator coil 222 is driven in a well-known manner by the servo electronics of the disk

drive to move actuator 216 such that head 224 is positioned over a desired radial position ("track") of disk 214.

Latch member pivot point 232 is positioned with respect to the actuator pivot point 226 so that tang or bump 248 is contacted by an angular protuberance 260 located on actuator arm 220 when it is moving towards a rest position over the landing zone 256. When contact is made, a torque is applied to latch member 230 to rotate it (clockwise in Fig. 7) to a position where hooked end 238 engages tip 258 of actuator 216.

A magnet assembly 262 is positioned near actuator coil 222, latch coil 242, and first and second magnetic masses 240 and 246. According to as presently preferred embodiment, which may be seen in phantom lines in Figs. 8A and 8B, and in top and side views in Figs. 10A and 10B, magnet assembly 262 comprises permanent magnets 264 and 266 mounted to mounting plate 268. Magnet assembly 262 is positioned at a location over actuator coil 260 so that permanent magnet 266 and actuator coil 222 can control the actuator position by controlling electric current passing through the actuator coil 222 to apply a torque to actuator 216. Magnet assembly 262 is positioned such that the magnetic attraction between magnet 264 and iron mass 240 on first arm 234 of latch member 230 and applies a rotational force to latching member 230 in a first direction (clockwise in Figs. 7, 8A, and 8B) towards tip 258 on actuator 216. Permanent magnet 266 is positioned such that magnetic attraction between it and latch member coil 242 (when selectively energized) and iron mass 246 applies a rotational force to latch member 230, opposite to the rotational force exerted by the magnetic attractive force between iron mass 240 and magnet 264, which tends to rotate first arm 234 of latch member 230 in a second direction (counterclockwise in Figs. 7, 8A, and 8B) away from the actuator 216.

Because the forces of magnetic attraction between the magnetic assembly and the magnetic masses 240 and 246 on the first and second arms of the latch member vary inversely as the square of the distance between the two magnetic bodies, the magnetic attraction between the magnetic assembly and the magnetic masses disposed on the two arms of the latch member is such that a bi-stable system is created. The effect of the magnetic forces can be analogized to the

effects of the force of gravity acting on a ball poised at the top of a hill. As long as it is positioned at the crest of the hill its position will remain stable. If, however, it is positioned slightly to either side of the crest of the hill, gravity will cause it to roll down that side.

5 The size of iron masses 240 and 246, the relative positions of the permanent magnet assembly 262, and the latch member coil core 242, and the strength of the magnets 264 and 266 in magnet assembly 262, are chosen such that, the rotational force exerted by the magnetic force of attraction between magnet assembly 264 and the latch member coil 242 when the coil is energized
10 exceeds the rotational force exerted by the magnetic attraction between iron mass 240 and magnet assembly 264. The result is that latch member 230 is rotated from the closed position to the open position and remains at rest in a position out of the arc of movement of actuator tip 258 when the head 224 is positioned over the data area 254 of the disk. When latch member coil 242 is not energized, the
15 latch member 230 is statically kept at either its open or closed position

In an illustrative embodiment of the present invention, latch member coil 240 may comprise about 240 turns of #46 AWG wire wound to an outside radius of about 0.3556 cm (0.14 in), an inside radius of about 0.254 cm (0.10 in), and a height of about 0.13462 cm (0.053 in). Magnet assembly 264 may include NdBF_e
20 rare-earth magnets having a strength of about 32 MGOe, such as grade NA32B available from Ugimag of Valpariaso, Indiana.

The latch apparatus of the present invention is activated when the power is cut to the spindle motor 212. Switching circuitry in the disk drive is activated to apply the back EMF generated by the still-rotating spindle motor 212 to the
25 actuator coil 222. The interaction between the magnetic field produced around the actuator coil 222 from the coil current resulting from the back EMF and magnet assembly 262 applies a torque to the actuator 216 which rotates it in a direction such that the head 224 moves towards a position over landing zone 256 of disk 214. As the actuator 216 moves in this direction, the tip 258 moves
30 towards the hooked end 238 of the latch member 230. During its travel, the angular protuberance 260 of actuator 216 contacts the tang or bump 248 of the latch member 230 and accelerates first arm 234 and its hooked end 238 of the

latch member 230 to a position where it receives the tip 258 of the actuator 216, thus locking the actuator 216 in the parked position. In this position, iron mass 240 is positioned closer to magnet assembly 262 than iron mass 246 and the clockwise rotational force caused by the magnetic attractive force between the two holds first arm 234 of latch member 230 against closed-position stop 252 located at a position on the disk drive frame which assures that tip 258 of actuator 216 remains captured by hooked end 238 of latch member 230.

In order to release the tip 258 of actuator 216 from the hooked end 238 of latch member 230 when it is desired to activate the disk drive and un-park the actuator 216, a current is passed through actuator coil 218 and applies a counterclockwise torque to rotate tip 258 away from hook 238. Then, a momentary current is passed through the latch member coil 240. The magnetic field created by the latch member coil current creates a magnetic attractive force between the latch member coil 240 and the permanent magnet assembly 262. This force applies a counterclockwise rotational force to the latch member 230 which overcomes the attractive force between magnet assembly 262 and iron mass 240, thus rotating its first arm 232 away from the actuator tip 258 and position the hook 238 out of the arc of movement of actuator tip 258. As iron mass 246 moves closer to magnet assembly 262, iron mass 240 moves further away. The counterclockwise rotational force caused by the magnetic attractive force between iron mass 246 and magnet assembly 262 moves first arm 234 of latch member 230 to open-position stop 250 and holds it there. Open-position stop 250 is located at a position on the frame 210 of the disk drive which assures that tip 258 of actuator 216 is free of hook 238 of latch member 230.

Those of ordinary skill in the art will recognize that the latching apparatus according to the present invention relies on static magnetic forces during operation of the disk drive. Spring forces may be used to substitute for these forces. The only power-supply current which is consumed during operation of the latch is that used to momentarily energize latch member coil 242 when it is desired to un-park the actuator.

Mechanical Shock Protection System

As development continues, disk drives are continually shrinking in size to accommodate new applications. As disk diameters become smaller, the issue of damage from mechanical shock begins to become a significant factor. As continuing evolution shrinks disk diameters below 5.08 cm (2 in), mechanical shock becomes a major concern for the first time.

The present concern over the issue of potential damage from mechanical shock results from the development of the small disk drives which are designed to reside in small lap-top and notebook portable computers. Larger disk drives (i.e., 13.335 cm (5.25 in) and 8.89 cm (3.5 in)) are generally mounted into larger computer systems housed in larger cases, usually residing on desk tops, or in even larger tower cases which are placed on the floor. In these environments, the 13.335 cm (5.25 in) and 8.89 cm (3.5 in) drives are generally quite safe from damage due to accidental mechanical shocks.

The smaller 6.35 cm (2.5 in) drives are employed in lap-top computers, an environment in which they are much more likely to be bumped and jostled. A lap-top computer system weighs from about 5 to 15 pounds. This weight helps lower the peak g-force experienced by the hard disk drive inside the lap-top computer when it is subjected to most mechanical shocks which can be anticipated to occur in its operating environment.

A major market which appears to be developing for 4.8 cm (1.89 in) drives is the palm-top computer. The palm-top computers will be very small and will probably weigh only about 1 to 2 pounds, and can be moved very quickly compared to the lap-top units. Also, palm-top computers are more susceptible to being accidentally bumped, jarred, or even dropped during operation. Because of their low weight, the small disk drive in a palm-top computer can be subjected to a substantial amount of mechanical shock during normal operation of the computer.

There are some effects of mechanical shock which are unpreventable. The worst-case preventable condition, resulting from mechanical shocks, occurs when the drive is writing data to a disk. In this state, the head is positioned over the proper track to record the data. If the mechanical shock is severe enough to

cause the head to move over an adjacent data track before the write current in the data head is turned off, the data in the adjacent track will be corrupted. This damaged data is not recoverable. Neither the computer nor disk drive controller know what data was damaged, when and how it was originally generated, and has
5 no way to fix the damaged data. The user will not even know that the data has been corrupted until a read failure is experienced at some later time. It will then be too late to reconstruct the corrupted data unless it has previously been backed up.

According to a preferred embodiment of the present invention, apparatus
10 is provided for preventing data corruption on a disk due to mechanical shock experienced by the disk drive during the write process to the disk. Mechanical shock sensing means are provided to sense mechanical shocks having a magnitude exceeding a predetermined threshold. If an above-threshold mechanical shock is sensed during a disk write operation, write disable means responsive to the
15 mechanical shock sensing means is activated and interrupts the write current to the disk drive write head. Because the mechanical shock is sensed and the write current is turned off before the write head moves off track, the corruption of data on adjacent tracks is avoided. Recovery means are provided to reposition the head to the original data track and rewrite the incompletely written data that was
20 interrupted by the mechanical shock. Thus, the mechanical shock causes only a minor delay to the user, but prevents corruption of the data on adjacent tracks by write head misalignment caused by the mechanical shock.

A method according to the present invention for preventing data corruption on a disk due to mechanical shock experienced by the disk drive
25 during the write process to the disk includes the steps of sensing a mechanical shock having a magnitude exceeding a predetermined threshold; interrupting the write current to the write head during the duration of the sensed mechanical shock; storing information identifying the data being written at the onset of the sensed mechanical shock; repositioning the head to the original data track; and
30 rewriting the data which was interrupted because of the sensed mechanical shock.

Referring now to Fig. 11, an apparatus 310 for preventing data corruption in disk drives from mechanical shock during write operations according to the

present invention is depicted in block diagram form. The apparatus and method of the present invention prevents a data head from continuing to write data when mechanical shock to the drive threatens to force it off of the track to which the data is being written.

5 The preferred apparatus according to the present invention includes a mechanical shock transducer 312 for converting a mechanical shock into an electrical signal. Mechanical shock transducer 312 may preferably be a single-beam or dual-beam cantilever beam rotational accelerometer or other type of accelerometer. Mechanical shock transducer 312 should ideally be mounted in
10 the disk drive in a position and an orientation selected to maximize sensitivity of rotational movement about the actuator pivot point because this axis is the most sensitive to write errors caused by mechanical shock.

 The electrical output of mechanical shock transducer 312 drives the input of a signal conditioner 314. Signal conditioner 314 may be a high-input-impedance amplifier device such as an MOS transistor or equivalent. Those of
15 ordinary skill in the art will recognize that an inherent limitation which must be taken into account in the selection of signal conditioner 314 is the need to minimize the time delay between the sensing of the shock and the operation of the apparatus of the present invention. If the delay is too long, the write current
20 to the write head will not be interrupted before the head strays over an adjacent track and irreparably corrupts already written data on that track.

 The output of shock-signal conditioner 314 is used as a switching signal input to provide a mechanical-shock-present signal to disk write electronics 316 to interrupt the write current to write head 318. The particular configuration of
25 the switching circuitry employed in disk write electronics 316 to perform this function will depend on the existing circuitry employed in disk write electronics 316. Those of ordinary skill in the art will realize that the switching configuration chosen for use in individual disk drives is a matter of trivial design choice and depends on the particular circuit configuration encountered in disk write
30 electronics 316 for individual disk drives.

 In a typical disk drive, a controller 320 normally provides signals to drive a data buffer 322. Data buffer 322 is used to store data obtained from bus 324

to be written to the disk. Bus 324 is usually the internal data bus of the computer containing the disk drive. According to the present invention, the mechanical-shock-present signal from the output of shock-signal conditioner 314 is used by controller 320 to cause it to identify which block of data is being written to the disk at the time the apparatus of the present invention interrupts the current to the write head 318 in response to a mechanical shock.

The mechanical-shock-present signal can be stored in a latch 326 which is interrogated by the controller 320 at the end of writing each block of data. If there has been no shock, the controller will continue normally with its next operation. If a shock has occurred, the latch 326 will be set, and the controller will interrupt its normal routine, will reposition the data head over the original data track, and will rewrite the entire block of data which was being written when interrupted by the shock. Finally latch 326 will be reset. Schemes similar to the latch embodiment described herein will readily suggest themselves to those of ordinary skill in the art.

Both the normal and shock-interrupted controller software routines are designed based on the particular hardware configuration encountered and will be a routine exercise for a skilled programmer. For maximum data integrity, the controller maintains the original data in the data buffer until it is written successfully to the disk without interruption by shock during the write cycle. New data is not lost, since the drive will quit transferring new data into the data buffer until the data already in the data buffer is successfully written. If necessary, the host computer will wait until the drive is ready to accept the new data.

After the shock has ceased, as indicated by the state of the mechanical-shock-present signal from the output of shock-signal conditioner 314, a software routine may be invoked to rewrite the interrupted data. As previously mentioned, the design of such software routines for individual systems will depend on the particular hardware configuration encountered and will be a routine exercise for a skilled programmer.

Presently preferred shock sensors according to the present invention are single-beam and dual-beam cantilever-beam rotational accelerometers, such as the ones depicted in Figs. 12A-12D. Referring first to Figs. 12A and 12B, an

illustrative single-beam cantilever-beam rotational accelerometer 330 comprises a support post 332 or other supporting structure which supports a cantilevered beam 334. A mass 336 is affixed to the distal end of cantilevered beam 334. According to a presently preferred embodiment, cantilever-beam strain gauge 330 may be fabricated from a single piece of sheet metal, such as 0.003 to 0.0381 cm (0.015 in) thick, and support post 332 and mass 336 may be formed by rolling the ends of the piece of sheet material. Alternatively, support post 332 may be realized by bending a flat end of the sheet metal to create an angled support post member. It is presently contemplated that other resilient materials, such as plastics, stainless steel, and printed circuit board material may also be employed.

The length of beam 334 may be between about 0.1905 cm (0.075 in) and 1.016 cm (0.400 in) and its width may be between about 1.27 cm (0.50 in) and 0.127 cm (0.050 in) according to a presently preferred embodiment. Presently preferred is a beam of thickness about 0.0305 cm (0.012 in), width about 0.2286 cm (0.09 in) and length about 0.762 cm (0.30 in). Mass 336 is selected for proper shock sensitivity threshold, and, in a presently preferred embodiment, should have a mass of between about 0.01 gm and 1.0 gm.

Sensor 338, preferably comprising a piezoelectric film, such as that available under the trademark Kynar from Atochem Sensors, Inc., of Valley Forge, PA, or that available under the trademark Solef from Solvay Technologies, Inc., of New York, New York, is fixedly mounted on the face of beam 334. Sensor 338 includes first and second electrical connections, preferably comprising wire 340 to eyelet connection 341 and connecting wire 342. A conductive trace disposed on the back side of the sensor film 338 makes an electrical connection to beam 334. The output signal of sensor 338 may thus be obtained between post 332 and wire lead 340 (340A, 340B in Fig. 12C). A typical output signal from sensor 338 is between about 0.1 mV to 1 V. Sensors of the type useful in the present invention are disclosed in the article D. Maliniak, Piezoelectric-Film Sensors Leave Niches Behind, Electronic Design, Vol. 39, No. 23, December 5, 1991.

Referring now to Figs. 12C and 12D, an illustrative dual-beam cantilever-beam rotational accelerometer 343 useful in the present invention comprises a

support post 342 which supports two cantilevered beams 344 and 346. In a presently preferred embodiment, cantilevered beams 344 and 346 may be oriented 180° with respect to one another, but other orientations may be possible for other particular sensing needs.

5 A mass 348A is affixed to the distal end of cantilevered beam 344 and a mass 348B is affixed to the distal end of cantilevered beam 346. The materials and construction of dual-beam cantilevered rotational accelerometer 343 may be the same as described for single-beam cantilevered rotational accelerometer 330, the only difference being the presence of the additional cantilevered beam.

10 Alternatively, other mechanical shock sensing means may be employed in the present invention. For example, it may be possible to employ an accelerometer, such as part No. ADXL50, manufactured by Analog Devices Corporation of Norwood Massachusetts. This part is designed to sense automobile collisions, or decelerations up to + 50 or -50 g's, in the forward or reverse direction (i.e., along one axis), and has a bandwidth of 1,000 Hz -- which is good enough for the air bag application, but, as presently configured, is too slow for the disk drive application. ~~Several approaches may be taken to speed up the response time.~~ It may be possible to increase the bandwidth to 2,000 Hz and above. In conjunction with this, either the intelligence of the microprocessor in the disk drive may be employed to monitor how fast the output of the ADXL50 is changing, or analog signal processing may be employed to perform the equivalent operation, and detect the severe shocks of concern faster. It may also be possible to speed up the ADXL50 accelerometer response time by modifying its closed-loop design to an open-loop design.

20 According to a presently preferred embodiment of the invention, the mechanical shock sensor is positioned in the disk drive so as to maximize sensitivity to rotation about the axis of the voice coil actuator because this axis is the most sensitive to write errors caused by mechanical shock.

25 In the ideal orientation, which is with the beam located on the axis of the head rotation and oriented approximately parallel to the head arms, the sensor has maximum sensitivity to rotation with reduced sensitivity in the x and y directions (front-to-back and side-to-side) and almost no sensitivity in the z (top-

30

to-bottom) direction. If the sensor is slightly reoriented by tilting it off the vertical direction, it can be made sensitive in the z direction also. Since the drive is most sensitive to rotational movements, and has very reduced sensitivities in the x, y, and z directions, the sensor sensitivities can be tailored to match the shock vulnerabilities of the drive by varying the orientation of the sensor. The dual beam accelerometer has additional flexibility in matching the shock sensitivities of the drive in the x, y, z, and rotational directions, by summing the individually weighted outputs of the two beams differentially combined with tilting the beam. Alternatively, if necessary for space saving or other reasons, mechanical shock transducer 312 may be mounted elsewhere in the drive and its output calibrated to take into account the differences between its actual position and orientation and its ideal position and orientation on the measured force of mechanical shock to the disk drive.

Referring now to Fig. 13, a presently preferred method according to the invention for preventing data corruption in disk drives from mechanical shock during write operations is illustrated in flow diagram form. The steps of the method according to this aspect of the invention may be carried out using the apparatus disclosed herein or by employing other apparatus, the details of which will be apparent to those of ordinary skill in the art from a study of this disclosure.

According to the preferred method of the invention, a mechanical shock having a magnitude exceeding a predetermined threshold is first sensed by employing a suitable transducer. This is illustrated at step 350 in Fig. 13.

When a mechanical shock exceeding the threshold is detected, the write current to the write head is interrupted immediately. This step, illustrated at block 352, prevents data from being mis-written by the head as the shock causes it to stray over a track adjacent to the track for which it was intended.

After sensing the shock in the first step of the method according to the present invention, information identifying the data being written at the onset of the sensed shock is available to permit rewriting of the data after the shock has passed. This step, illustrated in block 354, may be carried out in a variety of ways, depending on the write-control electronics and write buffer structure

contained in the system in which the present invention is to be employed. For example, as presently preferred, latch 326 (Fig. 11) is set when the shock is sensed. Latch 326 is read by the controller each time it finishes writing a block of data. If the latch 326 is not set, the controller merely directs that the buffer be filled with the next record to be written, and then proceeds to write the new data. If, however, the latch 326 has been set, the controller knows that the write process has been interrupted by the apparatus of the present invention. The data head is repositioned to the original track as shown in block 356 and the data already in the buffer is rewritten. Latch 326 is then reset.

This process step may be easily implemented by a software routine which simply adds the step of interrogating the latch after each write cycle, and branching to a rewrite routine if the latch 326 is set. The latch 326 may then be reset by the controller after the rewrite operation has been completed. Particular code to be used with such a software routine is dependent on the hardware used and may be easily created by persons of ordinary skill in the art.

After the mechanical shock has passed, the data which was interrupted because of the sensed shock is rewritten, as illustrated in block 358. This step may be performed by rewriting the entire block of data which was in the data buffer at the time the shock was sensed. This step includes the step of re-enabling the write current to the write head and clearing the shock-sensing latch 326, as previously mentioned.

PCMCIA Form Factor Disk Drive

Referring now to Fig. 14, an exploded view of the hard disk drive component 12 of a preferred embodiment of the ultra-small form factor disk drive is shown. On the right of the drawing is the spindle motor assembly which is described in detail above. On the left is the remainder of the HDD assembly. Working from the top down is cover 410 which includes recessed fastener holes 412 and recessed label area 414 for attachment of a product label without increasing the thickness of the unit in the area of the label. Next is gasket cover 416, shaft 418, bearing sleeve 420, headstack assembly 422, actuator coil 222, top pole plate 424, latch magnet 266, VCM magnet 264, bottom pole plate 426 which,

in conjunction with top pole plate 424 and VCM magnet 264 form the magnet assembly referred to above as elements 262, 264, and 266. Continuing down, pin lock 428 holds latch body 228 to machined base 210. Motor flex fab 430 is a flexible circuit board providing power to the spindle motor. I.D. Crash Stop 432 prevents the flexures from running into the hub. Finally, flex assembly 434 comprises a flexible printed circuit for attaching the heads to the electronics and amplifying the signals from the heads.

In Fig. 15 an exploded view of the PCMCIA drive is shown. HDD 12 is at the top of the stack, insulating plastic sheet 436 protects printed circuit board ("PCB") 438 which is electrically connected to HDD 12 through aperture 440 in sheet 436 with connector 442. Bracket cover 444 completes the assembly. Trim plates 446, 448, 450 are utilized to improve the aesthetic appearance of the PCMCIA drive.

Female PCMCIA connector 452 protrudes horizontally from PCB 438. Figs. 16A and 16B depict the layout of the component contact pads of PCB 438. Fig. 16A depicts the bottom and Fig. 16B depicts the top as referenced in Fig. 15. Surface mount devices are used throughout. The electronics for drive control are well understood in the art and therefore need not be described further herein. PCB 438 includes, according to one preferred embodiment of the present invention, shock sensor 454 which may be mounted within a void in PCB 438 as shown. According to a presently preferred embodiment of the present invention, the components on the surface of PCB 438 depicted in Fig. 16A should not extend more than 1.7 mm above the surface of the PCB. Likewise, the components on the surface of PCB 438 depicted in Fig. 16B should not extend more than 1.3 mm above the surface of the PCB. As to the side of PCB 438 shown in Fig. 16B, components may be placed where shown -- this area corresponds to a recess in the mating surface of the base plate or frame 210 (also labelled 112).

Turning now to Figs. 17A, 17B and 17C a top, side and front view, respectively, of a PCMCIA drive according to a preferred embodiment of the present invention are shown. PCMCIA connector 452 is disposed at the front of the drive for insertion into a mating double high PCMCIA connector/slot.

Thickness 456 is preferably 3.3 mm. The distance between point 458 and point 460 is preferably 10 mm. The distance between point 453 and point 455 is preferably about 12.6 mm. The distance between point 458 and point 466 is preferably about 85.6 mm. The distance between point 466 and point 468 is preferably about 0.65 mm. The distance between point 468 and point 470 is preferably about 3.3 mm. The total PCMCIA drive thickness is preferably less than about 10.5 mm for the double high PCMCIA connector/slot compatible version. The total PCMCIA drive thickness is preferably less than about 13.5 mm for the triple high PCMCIA connector/slot compatible version. The double high PCMCIA connector/slot has a width of about 54 mm and a height of about 10.5 mm. Turning to Fig. 17A, the width between side 468 and side 470 is preferably about 54 mm. The width of the HDD between HDD side 472 and HDD side 474 is preferably about 51 mm. The pin assignments of PCMCIA connector 452 are shown in Fig. 17C.

Accordingly, embodiments and applications of an ultra-small form factor disk drive apparatus capable of fitting into and mating with a double high PCMCIA standard connector/slot has been shown and described. It would be apparent to those skilled in the art that many more modifications than mentioned above are possible without departing from the inventive concepts herein. The invention, therefore, is not to be restricted except in the spirit of the appended claims.

CLAIMS

1. A rigid rotating disk drive system for removable attachment to a computer system comprising:

5 a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm;

a PCMCIA connector disposed horizontally from said housing;

the rigid rotating disk drive interfaceable to the computer system through a triple high PCMCIA connector/slot.

10 2. A rigid rotating disk drive system for removable attachment to a computer system comprising:

a housing having a width of no more than about 54 mm and a height of no more than about 10.5 mm;

a PCMCIA connector disposed horizontally from said housing;

15 the rigid rotating disk drive interfaceable to the computer system through a double high PCMCIA connector/slot.

3. A rigid rotating disk drive system for removable attachment to a computer system through a PCMCIA-type interface, said system comprising:

a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm; and

20 an integral spindle motor base plate assembly for a disk drive comprising:

a base plate including a recessed portion located therein, said recessed portion defined by a wall;

25 a spindle shaft centrally mounted in said recessed portion of said base plate, said shaft having a lower portion and an upper portion;

a stator fixedly mounted on said lower portion of said shaft and fully contained within said recessed portion, said stator having an outer diameter;

an upper bearing and a lower bearing mounted on said upper portion of said shaft;

30 an integral rotor assembly rotatably mounted onto said upper and

lower bearings, an upper portion of said rotor assembly adapted for mounting at least one disk thereto, and a lower portion of said rotor assembly in the form of a cylindrical band co-axial with said upper portion of said rotor assembly, said lower portion of said rotor assembly having an annular magnet mounted thereon, and extending downward into a region defined by said outer diameter of said stator and said wall defining said recessed portion of said base plate, said annular magnet contained fully within said recessed portion;

at least one disk mounted on said upper portion of said rotor assembly; and

a disk clamp mounted over said at least one disk and fastened to said upper portion rotor assembly by a fastening means substantially disposed at an axis of rotation of said rotor assembly for holding said disk in a fixed relationship with respect to said rotor assembly.

4. In a rigid rotating disk drive system for removable attachment to a computer system through a PCMCIA-type interface, said system including a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm and including an actuator mounted at a first pivot point, said actuator including a first radially-extending arm including a data head mounted thereon and a second radially-extending arm having an actuator coil mounted thereon, said first pivot point positioned with respect to a data disk so that said data head may be positioned over a data zone and a landing zone on said data disk, a static bistable mechanical disk drive actuator latch comprising:

a latch member mounted at a second pivot point, said latch member rotatable between an open position defined by an opened-position stop and a closed position defined by a closed-position stop, said latch member including first and second arms radially extending from said pivot point, said first arm including a hook located proximate to a distal end thereof and having a first magnetic mass mounted thereon, said second arm including an electromagnetic latch member coil and a second magnetic mass mounted thereon, and having a tang extending in a direction generally towards said actuator;

said second radially extending arm of said actuator including a

protuberance extending in a direction generally towards said tang, and a tip nestable in said hook;

said first and second pivot points positioned with respect to one another such that said tang will engage said protuberance at a predetermined position when said actuator is rotating so as to place said data head over said landing zone and such that said tip will be captured by said hook when said actuator is positioned such that said data head is over said landing zone and said latch member is in said closed position; and

a magnetic means positioned proximately to said actuator coil, said latch member coil, and said first and second magnetic masses;

wherein said magnetic means has a magnetic field strength selected such that, said magnetic means is positioned such that, and said first and second magnetic masses are sized such that, the rotational position of said actuator may be controlled by passing electric current through said actuator coil, a magnetic force of attraction between said magnetic means and said first magnetic mass will hold said latch member at said closed position, passing an electric current through said electromagnetic latch member coil will move said latch member to said open position, and a magnetic force of attraction between said second magnetic means and said magnetic mass will hold said latch member at said open position after the electric current is turned off.

5. In a rigid rotating disk drive system for removable attachment to a computer system through a PCMCIA-type interface, said system including a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm and including an actuator mounted at a first pivot point, said actuator including a first radially-extending arm including a data head mounted thereon and a second radially-extending arm having an actuator coil mounted thereon, said first pivot point positioned with respect to a data disk so that said data head may be positioned over a data zone and a landing zone on said data disk, apparatus for latching said disk drive actuator, comprising:

bistable mechanical latch means for latching said disk drive actuator, said bistable mechanical latch means including a first unlatched state in

which said actuator is free to move over said data zone, and a second latched state in which said actuator is confined over said landing zone, said bistable mechanical latch means including force-balancing means for statically maintaining said bistable mechanical latch means in either one of said first and said second states without application of electrical current;

latching means, responsive to an electrical latching signal, for switching said bistable mechanical latch means from said first unlatched state into said second latched state; and

releasing means, responsive to an electrical release signal, for switching said bistable mechanical latch means from said second latched state into said first unlatched state.

6. In a rigid rotating disk drive system for removable attachment to a computer system through a PCMCIA-type interface, said system including a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm, apparatus for preventing data corruption on a disk of a disk drive due to a mechanical shock experienced by said disk drive while writing data to a selected data track on said disk by passing a write-current to a write head disposed on a head arm of an actuator, said apparatus comprising:

mechanical shock sensing means for sensing mechanical shock having a magnitude exceeding a predetermined threshold and producing a shock-present signal in response thereto, said mechanical shock sensing means including a beam having a first end, a second end and a piezoelectric film strain sensor attached along a length of said beam, said second end having a mass of between 0.01 gm and 1.0 gm attached thereto, an electrical output of said piezoelectric film strain sensor carried on a pair of conductors;

write-disable means, responsive to said shock-present signal, for interrupting the write current to the write head;

interrupted-data identifying means, responsive to said shock-present signal, for identifying interrupted data being written at the time said shock-present signal indicates the presence of the mechanical shock; and

recovery means, responsive to said interrupted-data identifying means, for repositioning the write head over the selected track and for rewriting said interrupted data.

5 7. The apparatus of claim 6 wherein said first end of said mechanical shock sensing means is fixed along a mounting axis parallel to an axis of rotation of the actuator so as to permit rotational movement of said beam about said mounting axis in response to a shock applied to the disk drive about said axis of rotation.

10 8. The apparatus of claim 7 wherein said mechanical shock sensing means comprises an accelerometer.

9. The apparatus of claim 8 wherein said mechanical shock sensing means comprises a cantilever-beam accelerometer.

10. The apparatus of claim 8 wherein said mechanical shock sensing means comprises a single-beam cantilever-beam accelerometer.

15 11. The apparatus of claim 8 wherein said mechanical shock sensing means comprises a dual-beam cantilever-beam accelerometer having a beam positioned on an axis of rotation of the head arm.

20 12. In a rigid rotating disk drive system for removable attachment to a computer system through a PCMCIA-type interface, said system including a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm,

a method for preventing data corruption on a disk of a disk drive caused by mechanical shock experienced by said disk drive while writing data to an original data track with a data head, said method including the steps of:

25 sensing a mechanical shock having a magnitude exceeding a predetermined threshold with a mechanical shock sensor including a beam having

a first end, a second end and a piezoelectric film strain sensor attached along a length of said beam, said second end having a mass of between 0.01 gm and 1.0 gm attached thereto, an electrical output of said piezoelectric film strain sensor carried on a pair of conductors;

5 interrupting the write current to the data head of said disk drive during said mechanical shock;

 storing information identifying interrupted data being written when said write-current is interrupted;

 repositioning the data head to the original data track; and

10 rewriting said interrupted data.

13. In a rigid rotating disk drive system for removable attachment to a computer system through a PCMCIA-type interface, said system including a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm,

15 a method for preventing data corruption on a disk of a disk drive caused by a mechanical shock experienced by said disk drive while writing data to a data track with a data head, said method including the steps of:

 temporarily storing in a buffer a block of data to be written to the disk;

20 initiating a disk-write operation;

 temporarily storing a shock indicator signal in a selected storage location if a mechanical shock having a magnitude exceeding a predetermined threshold is sensed, said shock indicator signal derived from a mechanical shock sensor including a beam having a first end, a second end and a piezoelectric film strain sensor attached along a length of said beam, said second end having a mass of between 0.01 gm and 1.0 gm attached thereto, an electrical output of said piezoelectric film strain sensor carried on a pair of conductors;

25 interrupting the write current to the data head if said mechanical shock is sensed;

30 examining said selected storage location for said shock indicator signal after completion of said disk-write operation; and

repositioning the data head to the data track and rewriting said block of data if said shock indicator signal is present.

14. In a rigid rotating disk drive system for removable attachment to a computer system through a PCMCIA-type interface, said system including a housing having a width of no more than about 54 mm and a height of no more than about 13.5 mm, said disk drive system comprising:

at least one disk surface capable of being rotated about a first axis;

a voice coil actuator capable of rotary motion about a second axis parallel to said first axis;

a head arm mounted on said voice coil actuator;

a write head mounted on said head arm and positioned over said disk surface by said voice coil actuator;

said write head adapted to write information to a track of said disk surface in response to a write-current passed through said write head;

mechanical shock sensing means for sensing a mechanical shock having a magnitude exceeding a predetermined threshold and producing a shock-present signal in response thereto, said mechanical shock sensing means including a beam having a first end, a second end and a piezoelectric film strain sensor attached along a length of said beam, said second end having a mass of between 0.01 gm and 1.0 gm attached thereto, an electrical output of said piezoelectric film strain sensor carried on a pair of conductors;

write disable means, responsive to said shock-present signal, for interrupting said write-current to said write head;

interrupted-data identifying means, responsive to said shock-present signal, for identifying interrupted data being written at the time said shock-present signal indicates the presence of a mechanical shock exceeding said predetermined threshold; and

recovery means for repositioning said write head over said track and rewriting said interrupted data if said shock-present signal indicates the presence of a mechanical shock exceeding said predetermined threshold.

15. A disk drive system according to claim 14 wherein said first end of said beam is mounted along a third axis parallel to said first axis so as to permit rotational movement of said beam about said third axis in response to a shock applied to the disk drive about said first axis.

5 16. A disk drive system according to claim 14 further comprising a printed circuit board contained within the housing wherein said mechanical shock sensing means is mounted to said printed circuit board.

10 17. A disk drive system according to claim 16 wherein said mechanical shock sensing means is mounted within a void in said printed circuit board.

18. A disk drive system comprising:
at least one disk surface capable of being rotated about a first axis;
a voice coil actuator capable of rotary motion about a second axis
parallel to said first axis;

15 a head arm mounted on said voice coil actuator;
a write head mounted on said head arm and positioned over said disk surface by said voice coil actuator;

said write head adapted to write information to a track of said disk surface in response to a write-current passed through said write head;

20 a housing within which is mounted a printed circuit board;
mechanical shock sensing means for sensing a mechanical shock having a magnitude exceeding a predetermined threshold and producing a shock-present signal in response thereto, said mechanical shock sensing means including a beam having a first end, a second end and a piezoelectric film strain sensor
25 attached along a length of said beam, said second end having a mass of between 0.01 gm and 1.0 gm attached thereto, an electrical output of said piezoelectric film strain sensor carried on a pair of conductors;

said printed circuit board containing a void;

said first end of said mechanical shock sensing means mounted to

said printed circuit board and said second end extending into said void;

write disable means, responsive to said shock-present signal, for interrupting said write-current to said write head;

interrupted-data identifying means, responsive to said shock-present
5 signal, for identifying interrupted data being written at the time said shock-present signal indicates the presence of a mechanical shock exceeding said predetermined threshold; and

recovery means for repositioning said write head over said track and
rewriting said interrupted data if said shock-present signal indicates the presence
10 of a mechanical shock exceeding said predetermined threshold.

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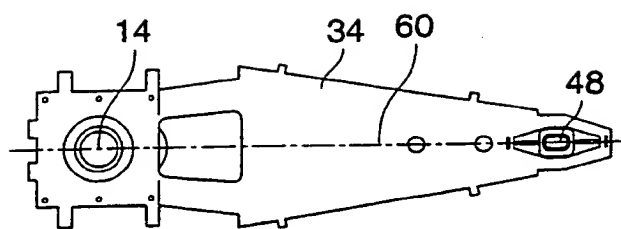


FIG. 1A



FIG. 1B

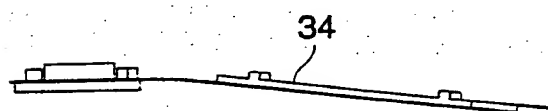


FIG. 1C

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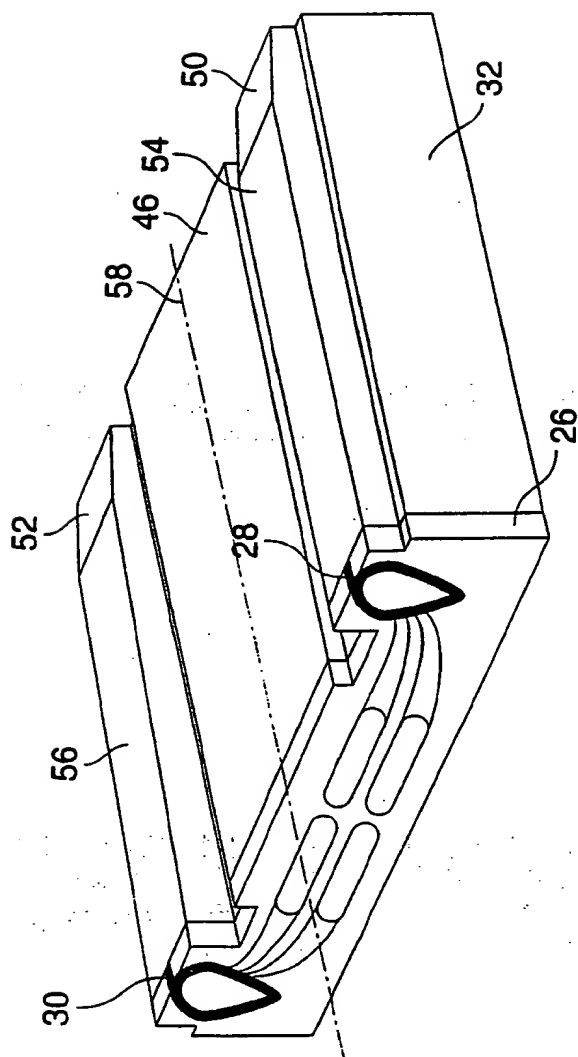
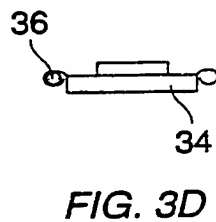
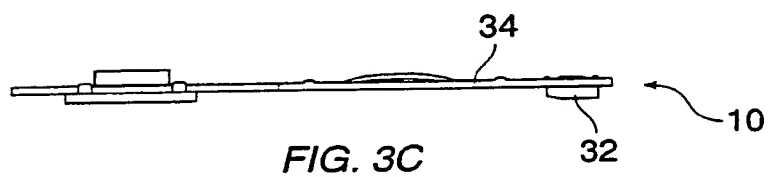
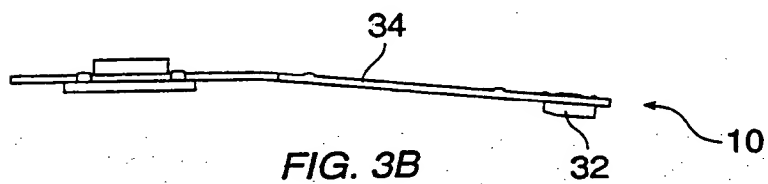
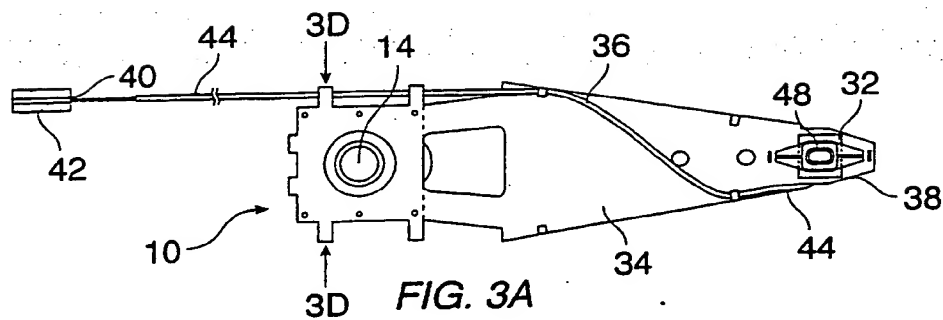


FIG. 2

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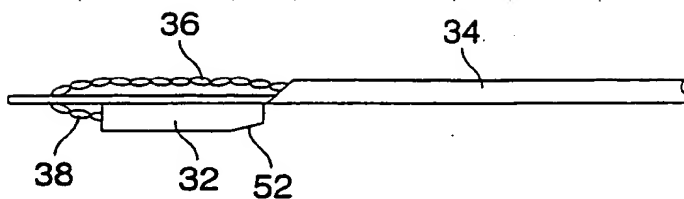


FIG. 4A

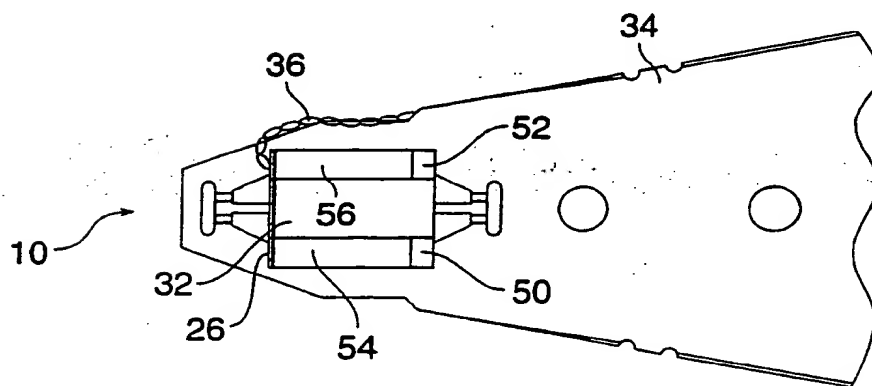


FIG. 4B

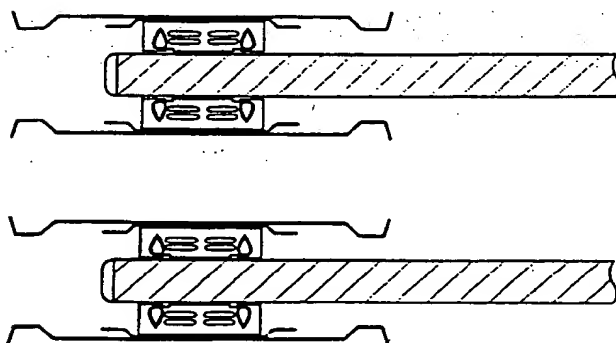


FIG. 5B

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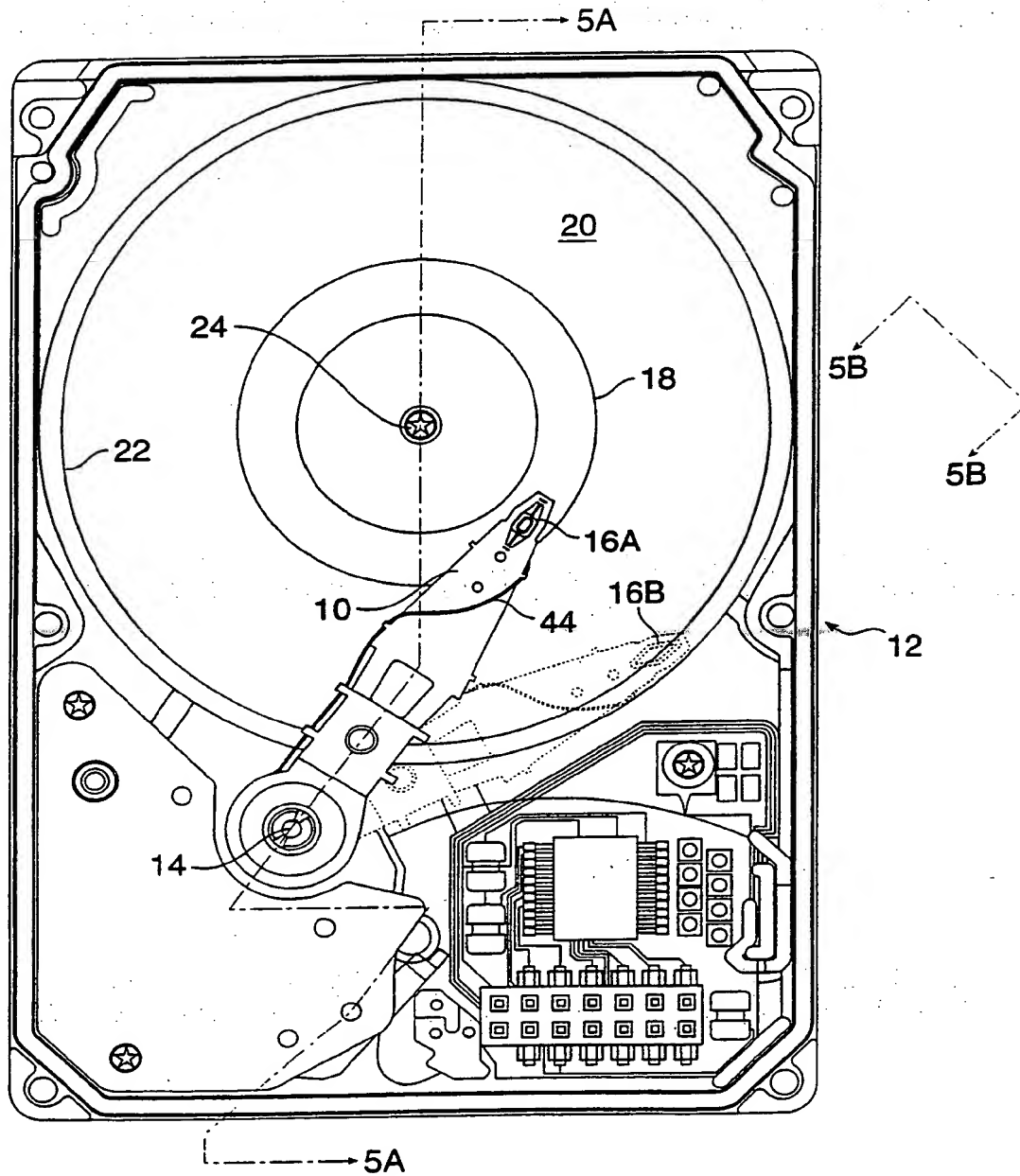


FIG. 5

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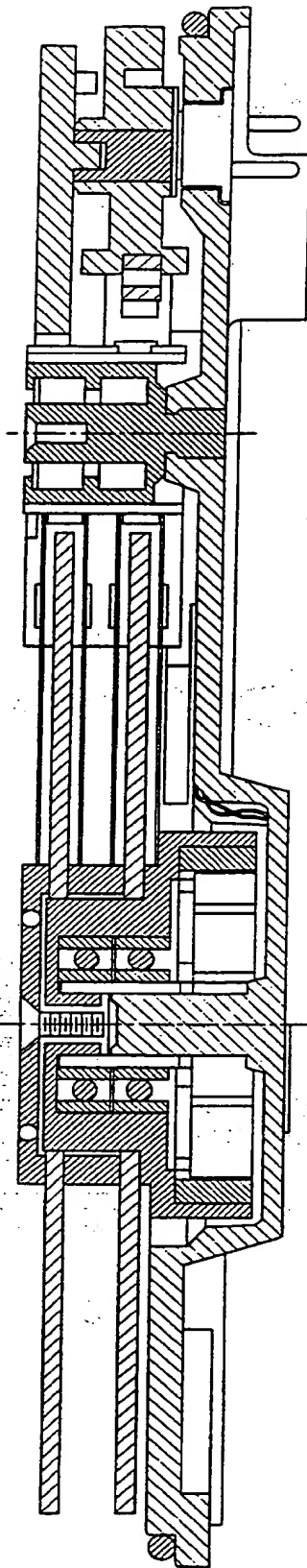


FIG. 5A

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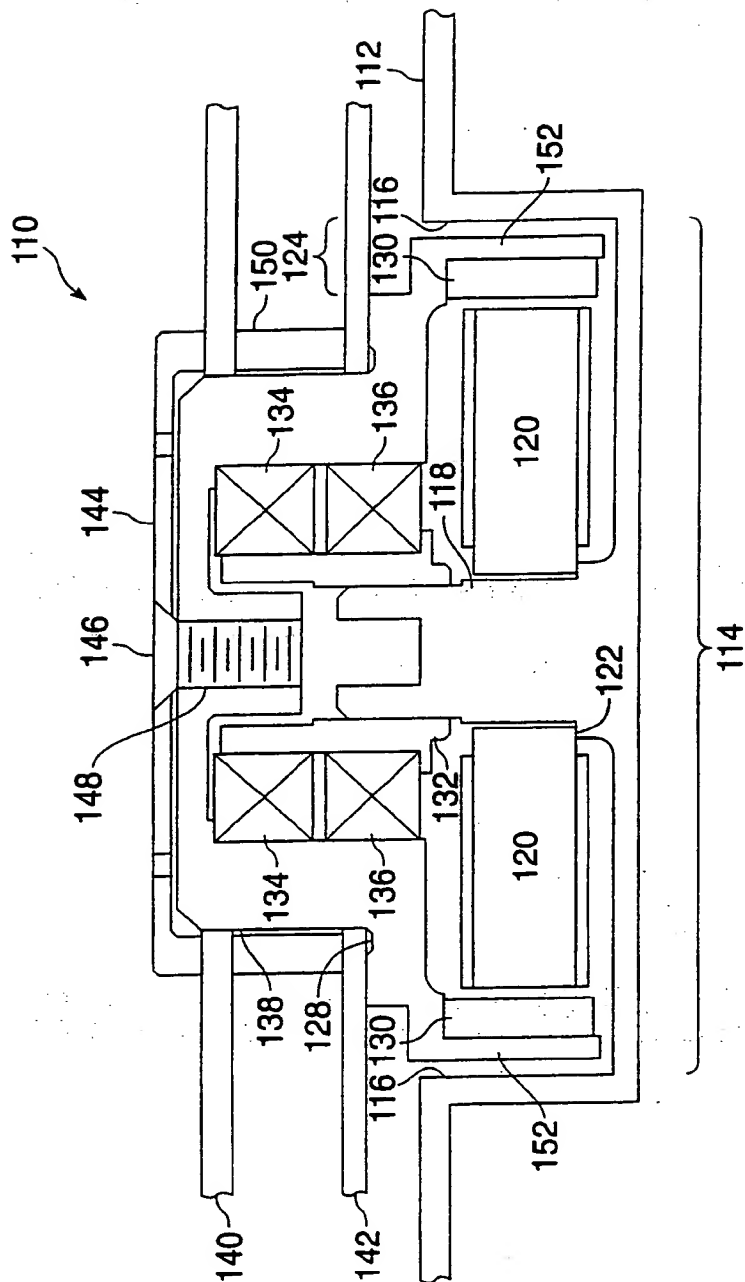


FIG. 6

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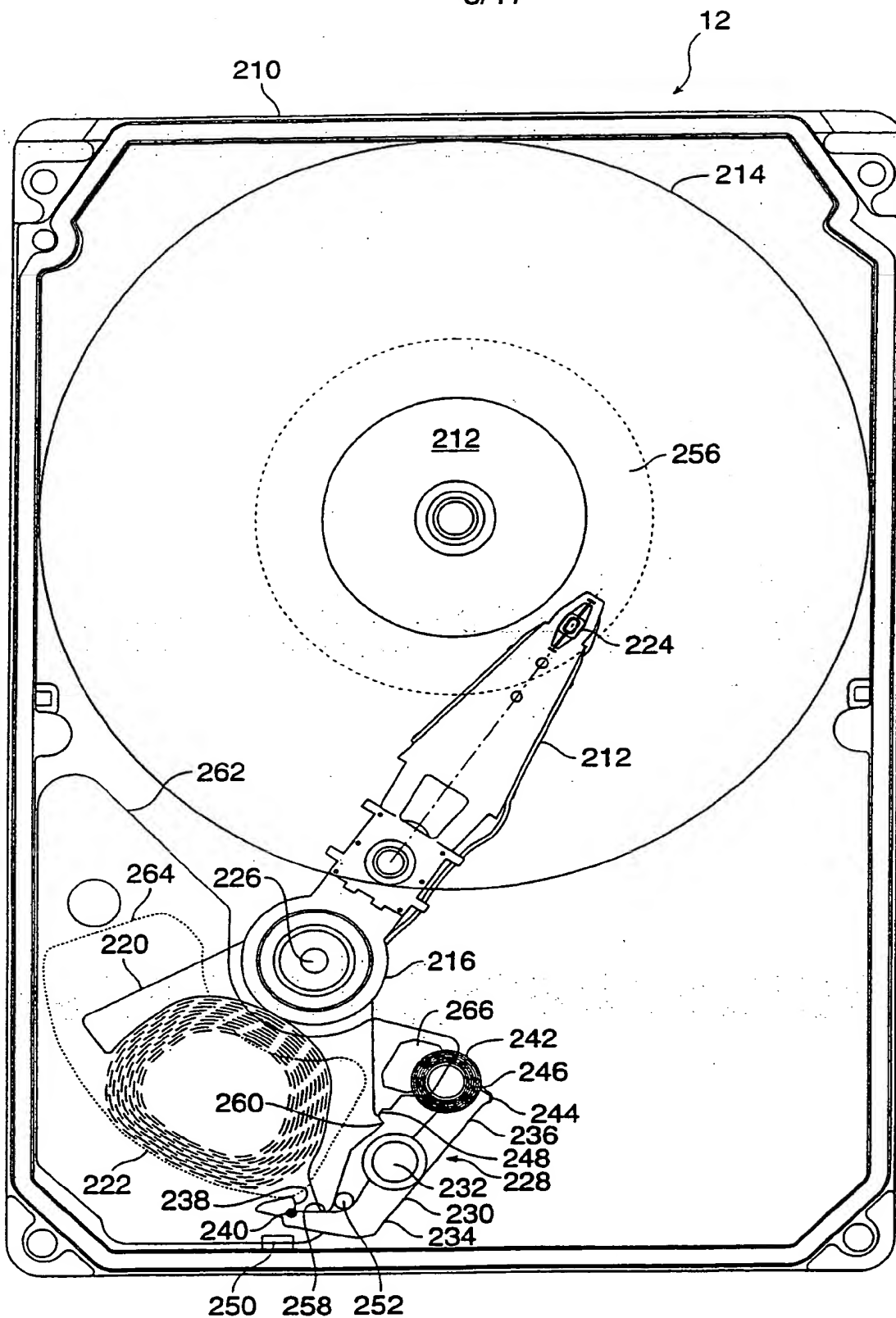


FIG. 7

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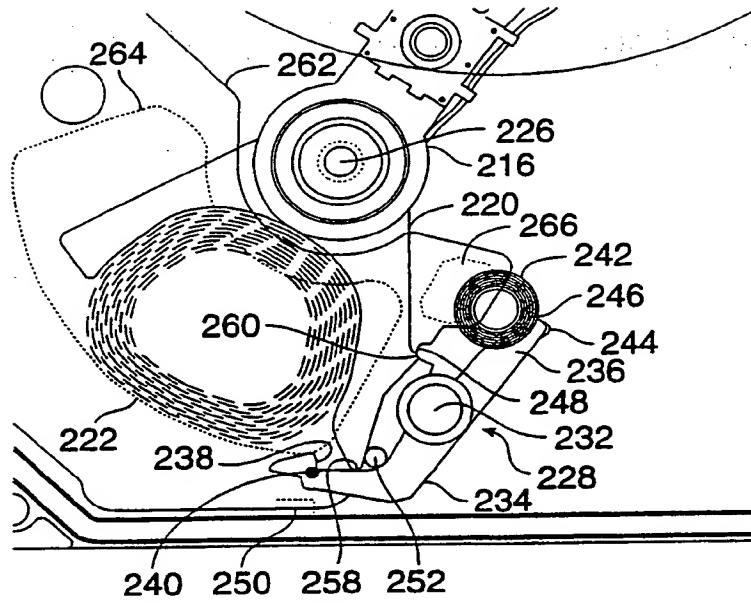


FIG. 8A

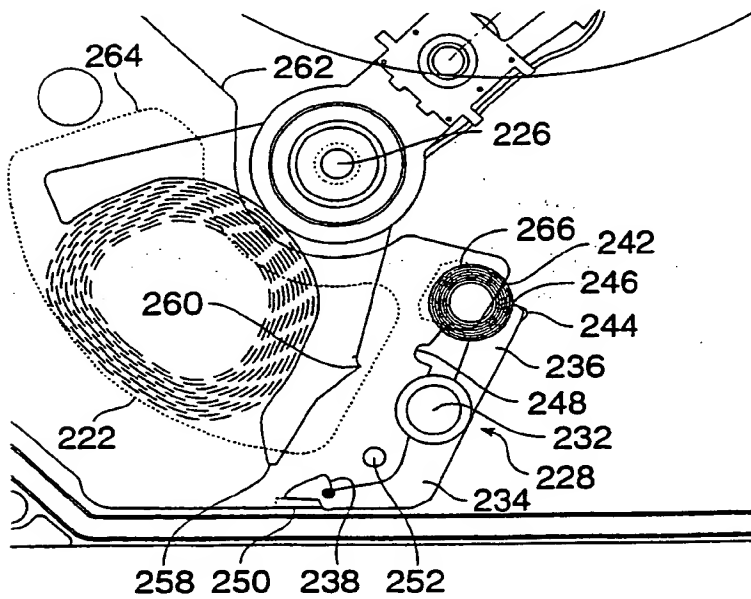


FIG. 8B

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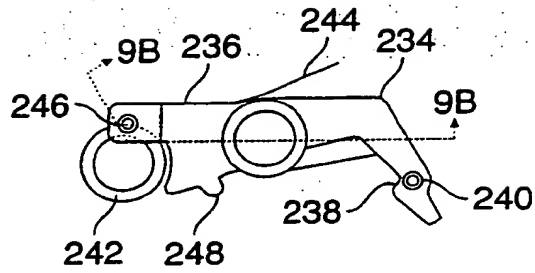


FIG. 9A

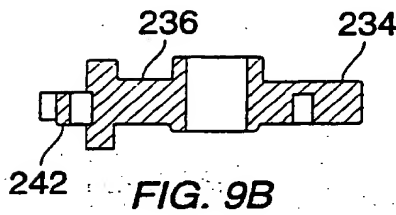


FIG. 9B

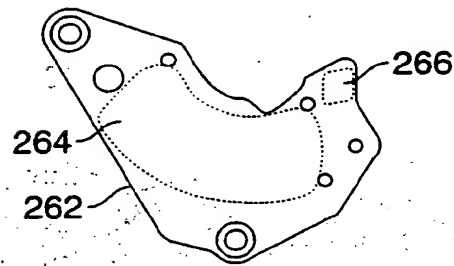


FIG. 10A

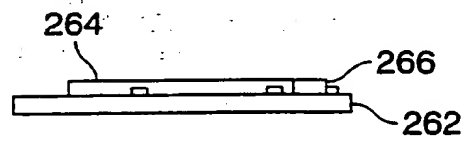


FIG. 10B

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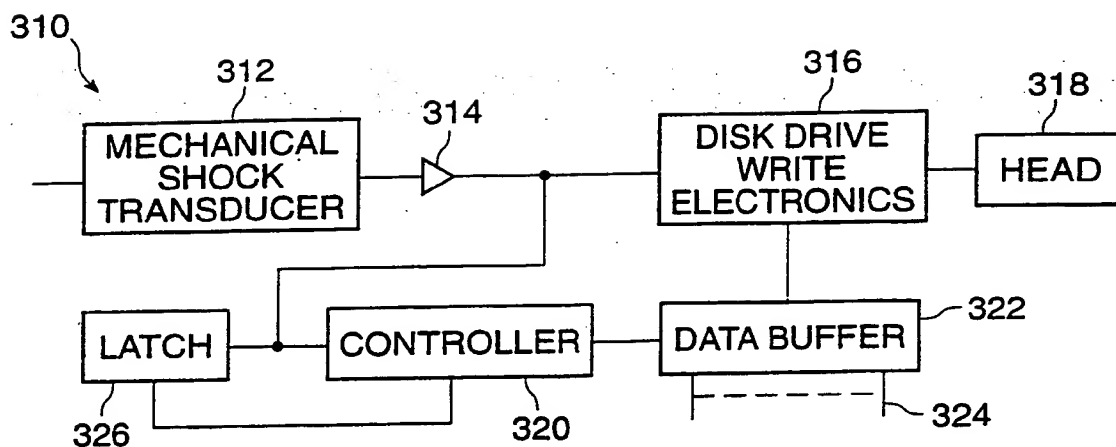


FIG. 11

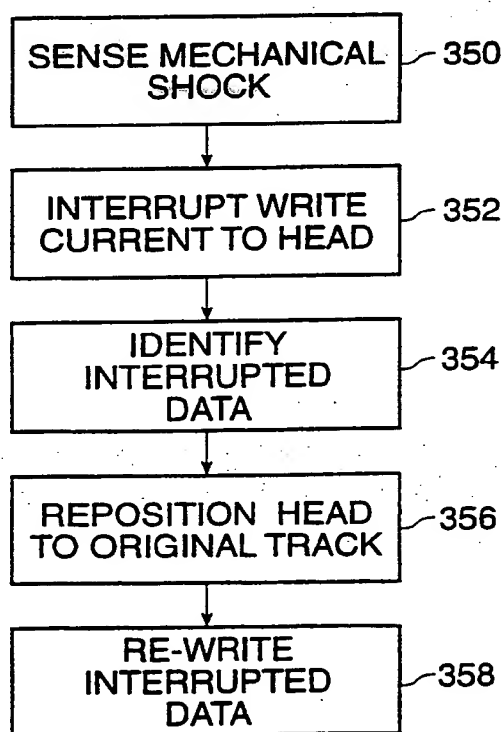


FIG. 13

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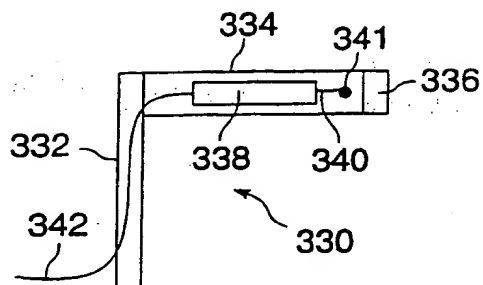


FIG. 12A

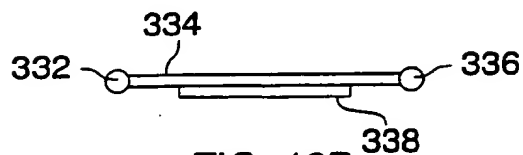


FIG. 12B

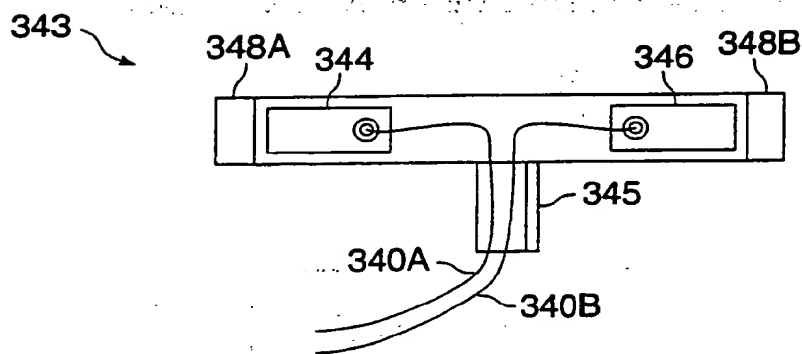


FIG. 12C

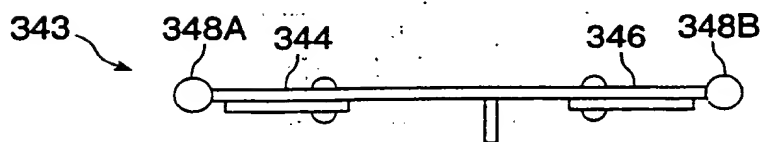


FIG. 12D

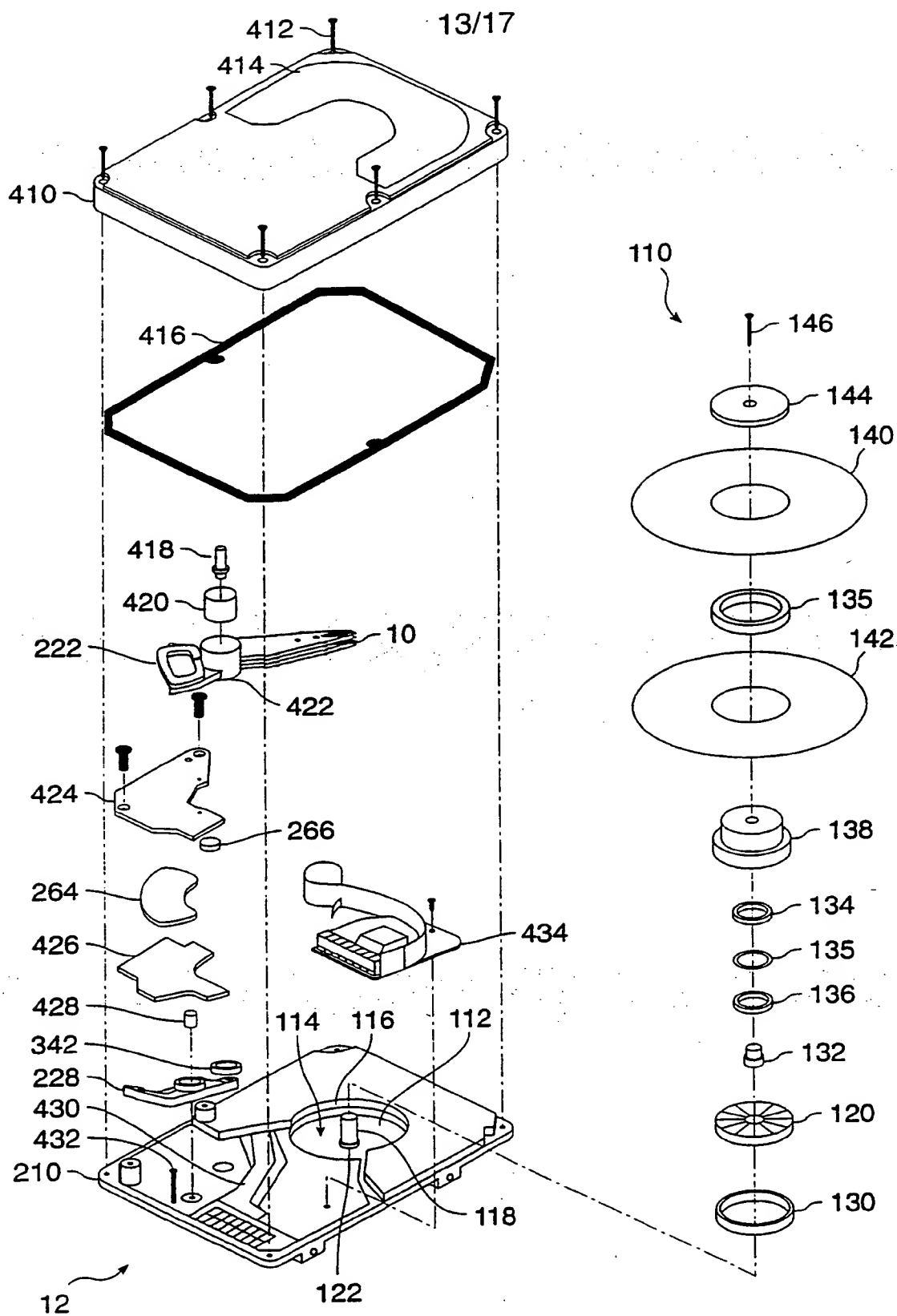


FIG. 14

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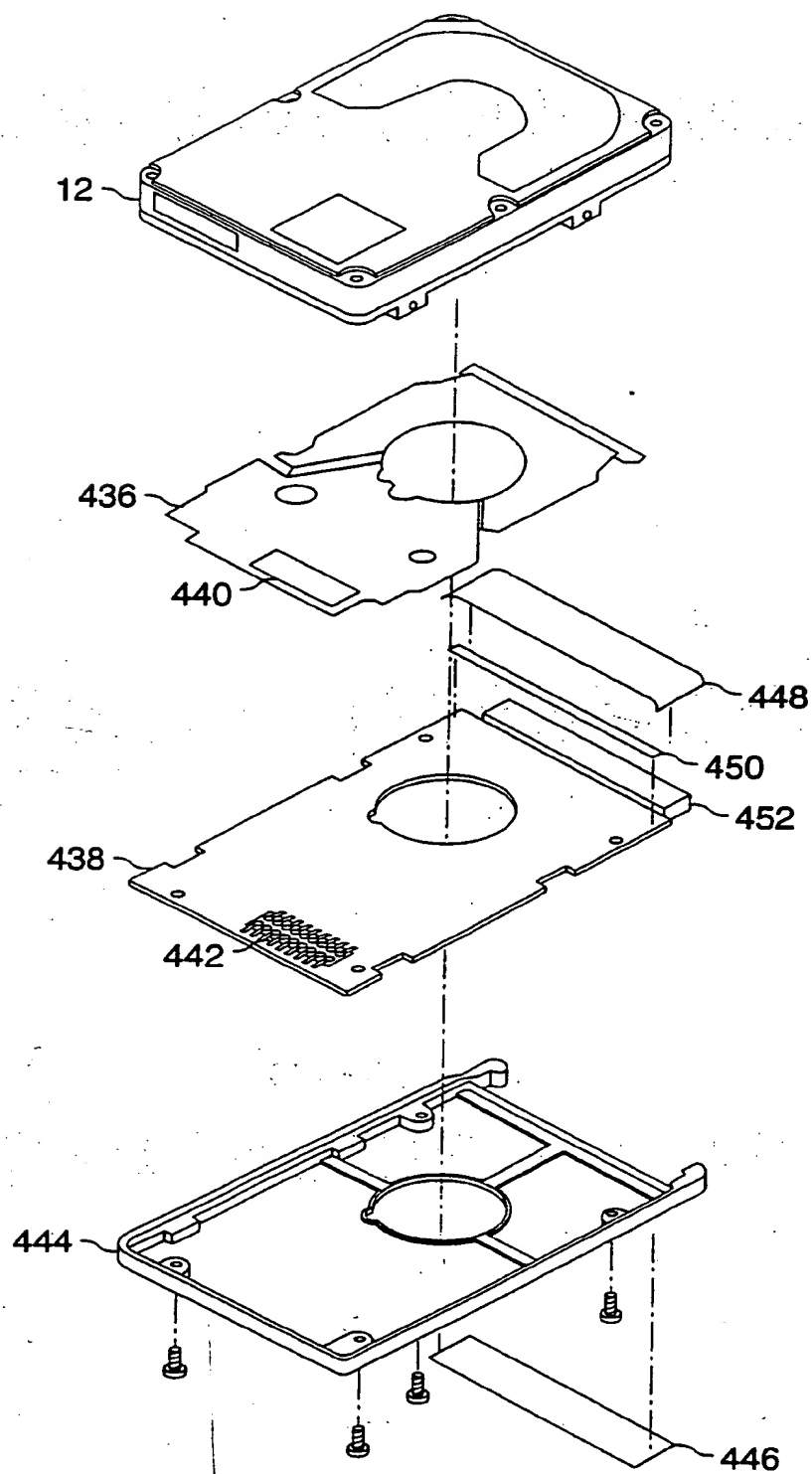


FIG. 15

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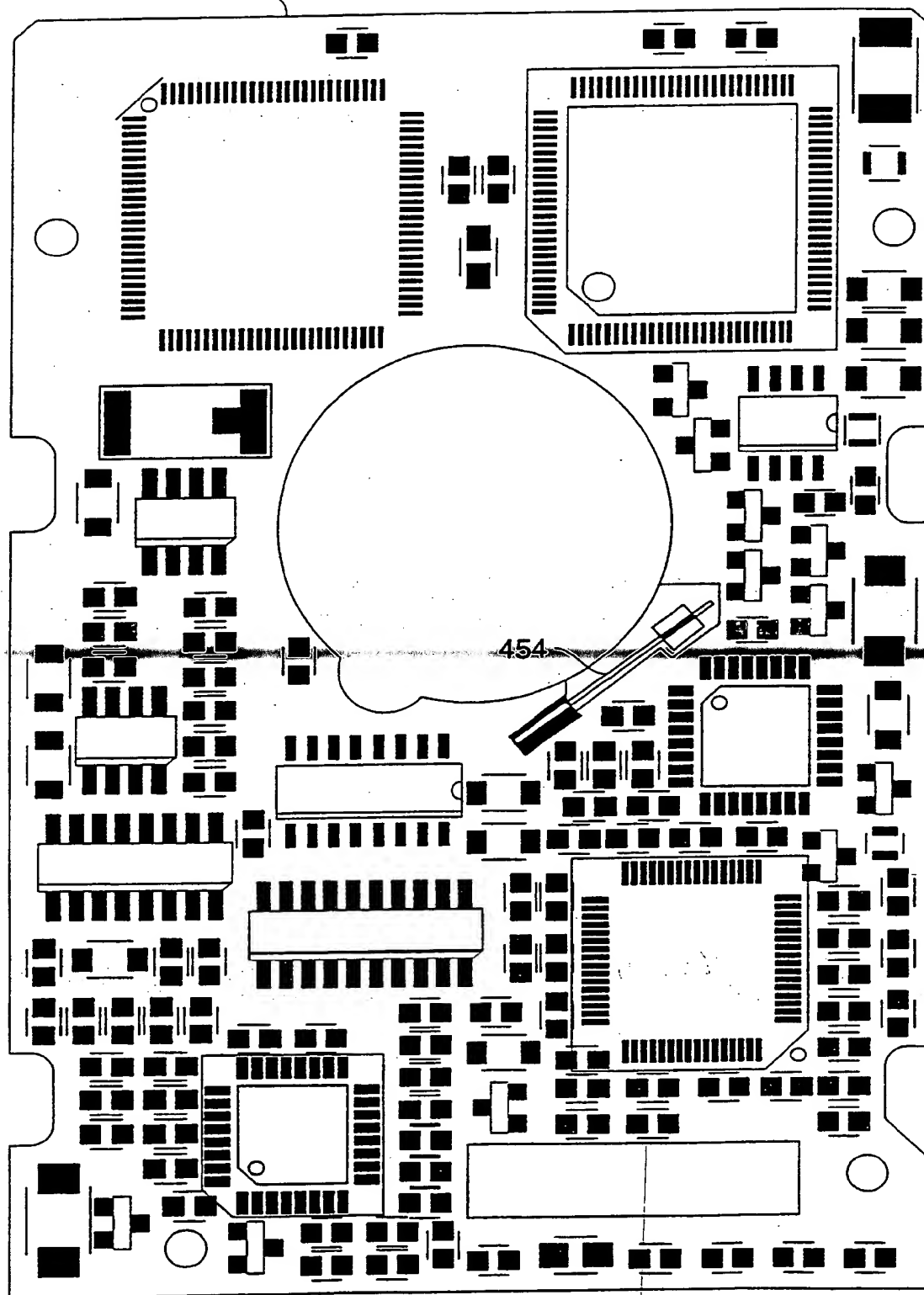


FIG. 16A

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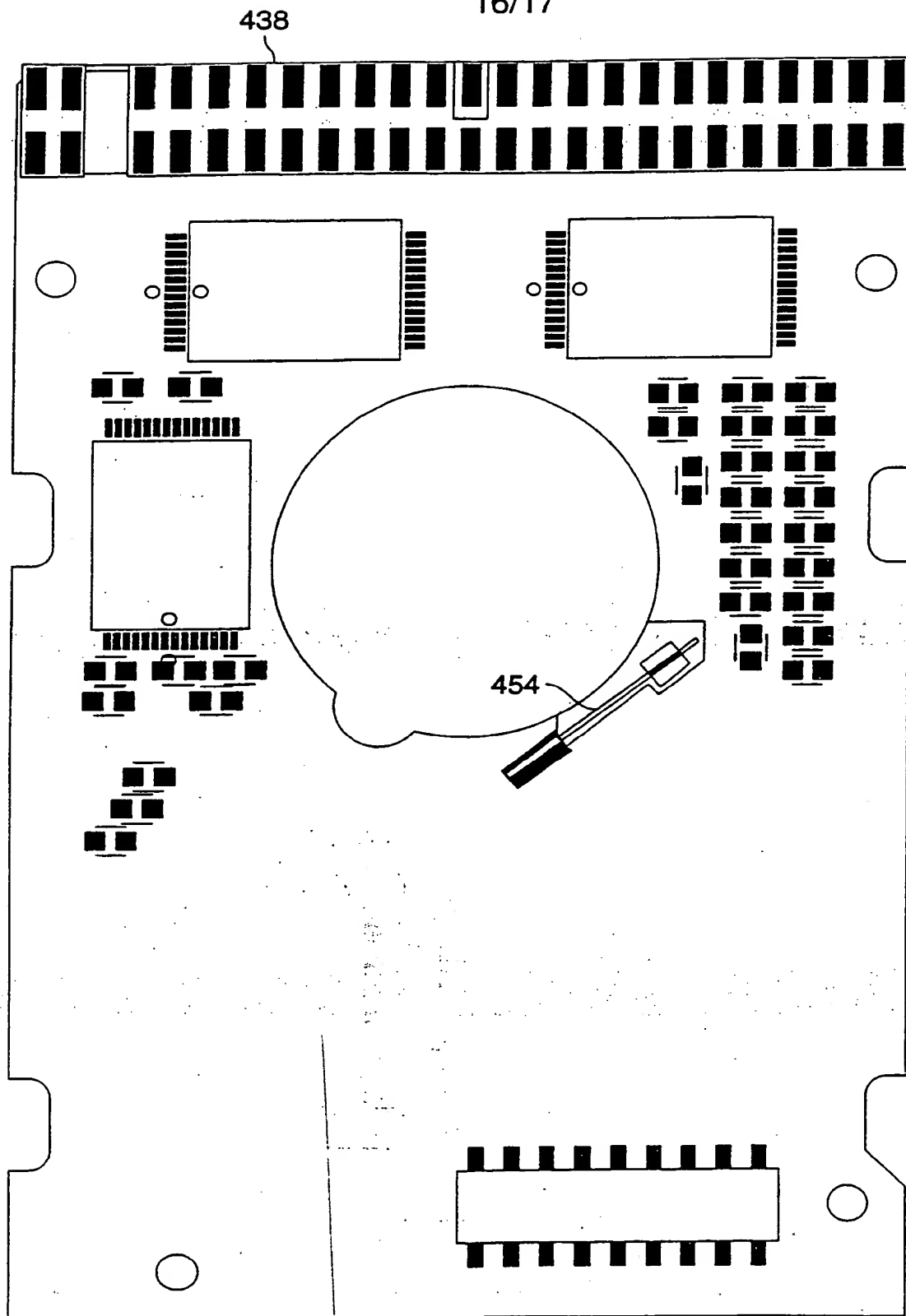


FIG. 16B

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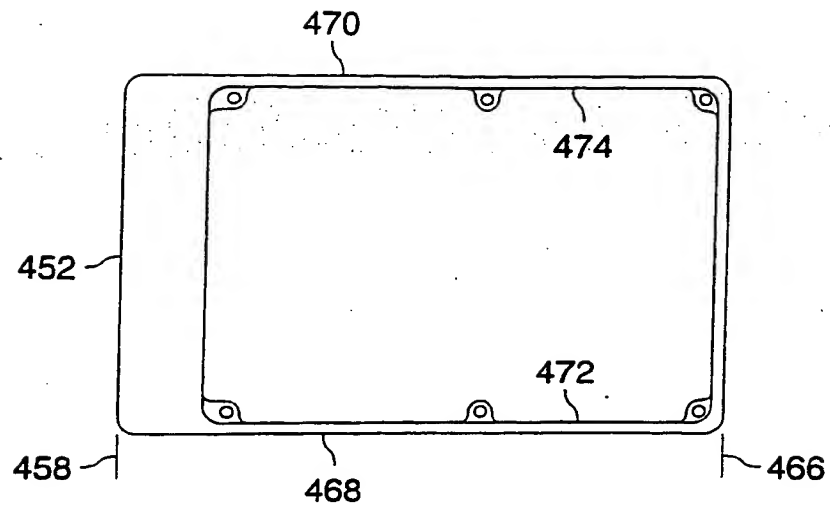


FIG. 17A

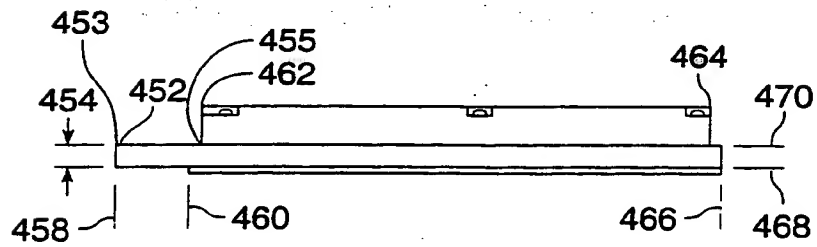


FIG. 17B

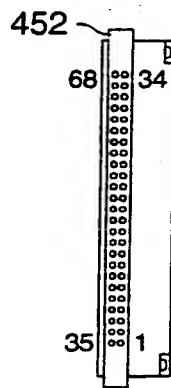


FIG. 17C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/03106

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : G11B 5/012, 5/54, 15/04, 17/02, 17/14, 21/22

US CL : 360/69, 97.01, 99.08, 105

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 73/ 517 AV, 517 R; 310/67 R; 360/60, 69, 97.01, 98.07, 99.04, 99.08, 105, 106

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,113,297 (Yoshida) 12 May 1992 see Fig. 3(B).	1,2
X,P	US, A, 5,251,082 (Elliott et al) 05 October 1993 see col.14, lines 47-54; col. 15, lines 7-20.	1,2
X	US, A, 5,047,677 (Mineta et al) 10 September 1991 see Figure 2.	3
Y,P	US, A, 5,208,713 (Lindsay et al) 04 May 1993 see Figures 4A-4C.	4,5
Y,E	US, A, 5,313,354 (Sampietro et al) 17 May 1994 see Figure 1.	4,5

☒ Further documents are listed in the continuation of Box C.
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O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
30 June 1994	JUL 13 1994

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WILLIAM R. KORZUCH

Telephone No. (703) 308-1296

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/03106

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US, A, 5,235,472 (Smith) 10 August 1993 see column 2, lines 32-49.	6-18
Y	US, A, 4,522,072 (Sulouff et al) 11 June 1985 see Abstract, Figure 3.	6-18
A,P	US, A, 5,264,975 (Bajorek et al) 23 November 1993 see Figure 3.	1-18
A	US, A, 5,177,650 (Jabbari et al) 05 January 1993 see Figure 2.	3
A	US, A, 4,833,550 (Takizawa et al) 23 May 1989 see Figure 1.	4,5
A	US, A, 4,862,298 (Genheimer et al) 29 August 1989 see Abstract.	6-18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/03106

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

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1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/03106

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : G11B 5/012, 5/54, 15/04, 17/02, 17/14, 21/22

US CL : 360/69, 97.01, 99.08, 105

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Y,P	US, A, 5,208,713 (Lindsay et al) 04 May 1993 see Figures 4A-4C.	4,5
Y,E	US, A, 5,313,354 (Sampietro et al) 17 May 1994 see Figure 1.	4,5

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* A* document defining the general state of the art which is not considered to be of particular relevance	* X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
* E* earlier document published on or after the international filing date	* Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
* L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another document for a special reason (as specified)	* &*	document member of the same patent family
* O* document referring to an oral disclosure, use, exhibition or other means		
* P* document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

30 June 1994

Date of mailing of the international search report

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